BIOLOGICAL AND ENVIRONMENTAL EFFECTS OF NUCLEAR WAR

HEARINGS

BEFORE THE

SPECIAL SUBCOMMITTEE ON RADIATION

OF THE

JOINT COMMITTEE ON ATOMIC ENERGY
CONGRESS OF THE UNITED STATES

EIGHTY-SIXTH CONGRESS

FIRST SESSION

ON

BIOLOGICAL AND ENVIRONMENTAL EFFECTS
OF NUCLEAR WAR

JUNE 22, 23, 24, 25, AND 26, 1959

Printed for the use of the Joint Committee on Atomic Energy

BIOLOGICAL AND ENVIRONMENTAL EFFECTS OF NUCLEAR WAR

HEARINGS

BEFORE THE

SPECIAL SUBCOMMITTEE ON RADIATION

OF THE

JOINT COMMITTEE ON ATOMIC ENERGY CONGRESS OF THE UNITED STATES

EIGHTY-SIXTH CONGRESS

FIRST SESSION

ON

BIOLOGICAL AND ENVIRONMENTAL EFFECTS
OF NUCLEAR WAR

JUNE 22, 23, 24, 25, AND 26, 1959

PART 1

Printed for the use of the Joint Committee on Atomic Energy

UNITED STATES
GOVERNMENT PRINTING OFFICE
43338 WASHINGTON : 1959

BIOLOGICAL AND ENVIRONMENTAL EFFECTS OF NUCLEAR WAR

MONDAY, JUNE 22, 1959

CONGRESS OF THE UNITED STATES,
SPECIAL SUBCOMMITTEE ON RADIATION,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10:13 a.m., in Senate caucus room, Hon. Chet Holifield presiding.

Present: Representative Chet Holifield, chairman; Representatives Price, Van Zandt, Hosmer, Bates, Westland; and Senators Anderson, Hickenlooper, and Aiken.

Also present: James T. Ramey, executive director; John T. Conway, assistant director; George E. Brown, Jr., professional staff member; and Col. Richard T. Lunger, staff consultant; Dr. Carey Brewer, special consultant, Joint Committee on Atomic Energy.

Representative HOLIFIELD. The committee will be in order.

Today the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy is beginning a series of public hearings on the biological and environmental effects of a possible nuclear war.

The subcommittee has, for some time, realized that considerable confusion exists in the public mind as to the probable effects of nuclear weapons and their aftermath in the event of their employment in war.

We believe it is in the national interest to clear up this confusion, and we believe that clarification can be accomplished within the limits of unclassified information.

It was apparent from the hearings held by this subcommittee in 1957, that there is a very large practical difference between the problem created by the worldwide fallout coming from a program of testing nuclear weapons, and those that would result from the use of these weapons in an all-out war. Accordingly, the fallout problems associated with the testing of nuclear weapons were considered in a separate hearing early in May of this year. It is our purpose to investigate the problems of nuclear war in the present hearing.

The contrast between the two types of problems may be illustrated by a few examples. The test program involves the detonation of 170 megatons of total yield. Ninety-two megations of this were due to the fisssion yield. These detonations have occurred over a 10-year period. The problems we will consider in the present hearings involve the detonation of 3,950 megatons total yield, of which 1,976 megatons are fission yield, all detonated within 1 day.

Biological half life	The biological half life of any element or radioactive nuclide is the time interval required to reduce the number of atoms present in the body to half of their initial value. The biological half life does not include the radioactive half life of a radioactive element.
Curie	That quantity of a radioactive nuclide disintegrating at the rate of 3.70 by 10^{10} atoms per second or 2.22 by 10^{12} atoms per minute. Abbreviated: c.
Micromicrocurie	1 million millionth of a curie or that quantity of a radioactive nuclide disintegrating at the rate of 3.7 by 10^{-2} atoms per second or 2.22 atoms per minute. Abbreviated: $\mu\mu$c.
Millicurie	1 thousanth of a curie or the quantity of a radioactive nuclide distintegrating at the rate of 3.70×10^7 atoms per second or 2.22×10^9 atoms per minute. Abbreviated: Mc.
Megacurie	1 million curies or the quantity of a radioactive nuclide disintegrating at the rate of 3.70×10^{16} atoms per second or 2.22×10^{18} atoms per minute.
Dose	The radiation delivered to a specified area or volume or to the whole body.
Effective half life	The time required for a radioactive element in the body to be diminished to half of its value as a result of the combined action of radioactive decay and biological elimination.
Electron volt	A unit of energy equivalent to the amount of energy gained by an electron in passing through a potential difference of 1 volt. Larger multiples of the electron volt are frequently used, viz, Kev. for thousand or kilo electron volts; Mev. for million electron volts; and Bev. for billion electron volts.
Erg	Unit of work or energy done by a unit force acting through unit distance. The nuclear unit of work or energy is the Mev. which is equal to 1.6×10^{-6} ergs.
Gamma ray	Electromagnetic radiation resulting from radioactive decay. Gamma rays have no mass and no charge, but have energy which ranges from Kev. to Mev.
Half life	The half life of a radioactive atom is the time interval over which the chance of survival is exactly one-half. In any large number of disintegrating radioactive atoms half of the atoms present at any time will decay during one-half life. The half life for a particular nuclide is given by $$\dagger\tfrac{1}{2} = \frac{0.693}{\lambda}$$ where λ is a constant for each nuclide.

Nuclide---------------------------------- A nuclide is the individual species of atoms in an element having a certain mass and a specific energy content. Therefore, more than 1 nuclide may compose an isotope. For example, Ba–137m (radioactive) and Ba–137 (stable) are nuclides of the same isotope.

Rad---------------------------------- The unit of absorbed dose, which is 100 ergs per gram. The rad is a measure of the energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest. It is a unit that was recommended and adapted by the International Commission on Radiological Units at the Seventh International Congress of Radiology, Copenhagen, 1953.

Relative biological effectiveness-------- The ratio of gamma or X-ray dose to the dose that is required to produce the same biological effect by the radiation in question.

REM---------------------------------- Roentgen equivalent man: that quantity of any type ionizing radiation which when absorbed by man produces an effect equivalent to the absorption by man of 1 roentgen of X- or gamma radiation (400 KV).

REP---------------------------------- Roentgen equivalent physical: the amount of ionizing radiation which will result in the absorption in tissue of 83 ergs per gram. (Recent authors have suggested the value of 93 ergs per gram.)

Stratosphere---------------------------- The upper portion of the atmosphere, above (11 km), more or less (depending on latitude, season, and weather) in which temperature changes but little with altitude and clouds of water never form, and in which there is practically no convection.

Stratospheric half life------------------ The time interval required to reduce the activity present in the stratosphere to half by removal from the stratosphere to the troposphere. Stratospheric half life does not include radioactive half life of any of the radioactive nuclides.

Strontium unit-------------------------- Formerly sunshine unit. 1 thousandth of the maximum permissible body level of Sr–90. It is equal to 1 micromicrocurie per gram of calcium.

Tropopause---------------------------- The imaginary boundary layer dividing the upper part of atmosphere, the stratosphere, from the lower part, the troposphere. The tropopause normally occurs at something like 35,000 to 55,000 feet altitude, although it depends on season and location.

Troposphere---------------------------- All that portion of the atmosphere below the stratosphere. It is that portion in which temperature generally rapidly decreases with altitude clouds form, and convection is active.

43338—59——2

Representative HOLIFIELD. As our first witness I shall call on Mr. Eugene Quindlen, of the Office of Civil and Defense Mobilization, to state for the record the basic assumptions drawn up by the subcommittee and used by the OCDM in their damage assessment for these hearings.

At a later point in the hearings the OCDM will be asked to present the results of their computations with respect to the structural damage and casualties which would be caused by the hypothetical attack presented by the subcommittee.

Representative HOLIFIELD. Mr. Quindlen, we are happy to have you before us this morning as the witness from OCDM and the chairman wishes to thank you on behalf of the Joint Committee on Atomic Energy for your cooperation during some 6 weeks we have been working to get this program in shape for presentation, and we wish to thank you personally for attending this morning. You may proceed.

STATEMENT OF EUGENE QUINDLEN,[1] OFFICE OF CIVIL AND DEFENSE MOBILIZATION

Mr. QUINDLEN. Thank you, Mr. Chairman, and our thanks to the members of the committee.

We are very pleased to be here because we believe, as you do, that people must be informed about the nature of the threat and about the actions which they take to meet the threat.

Informing the American people is a major aim of the Office of Civil and Defense Mobilization. We believe that an informed public—and we try our best to inform the public—will take the action which is necessary. We welcome any additional opportunity to bring this matter to public attention.

The attack to be considered during these hearings was specified by the committee. The Office of Civil and Defense Mobilization did not participate in the formulation of the attack pattern, but did do the assessment of the effects of this attack upon the United States.

The attack (Chart No. 1) consists of 263 weapons delivered on 224 targets in the United States. This is a net attack representing the number of weapons reaching the United States rather than the gross number with which the aggressor force might have started.

The total megatonnage of the attack was 1,446. The weapons used were 1 megaton in size—that is the equivalent of 1 million tons of TNT—2 megatons, 3 megatons, 8 megatons and 10 megatons.

---

[1] Eugene J. Quindlen is the Deputy Assistant Director for Federal, State, and Local Plans of the Office of Civil and Defense Mobilization. He has responsibility for advice and guidance to cities, States, and Federal agencies on civil-defense operational planning, for the program of providing matching funds to States and localities, for the surplus-property program of OCDM and for operational analysis.

Mr. Quindlen has held staff positions with OCDM and its predecessor agency, FCDA, since March 1951. He has participated in all phases of the planning of FCDA programs and has held responsible staff positions in the annual civil-defense exercise, Operation Alert. Previous assignments within FCDA include Deputy Assistant Administrator of the Planning Staff and Assistant Administrator of Operations.

Mr. Quindlen has 17 years of service with the Federal Government, including 4 years of active duty as a medical administrative officer with the Army Medical Department. He was also employed by the Veterans' Administration and had departmental and field experience in the Federal Security Agency, which is now the Department of Health, Education, and Welfare.

Mr. Quindlen holds a B.A. degree from LaSalle College, an M.A. degree in educational psychology and statistics from Fordham, and a law degree from Georgetown University. His graduate work included an assistantship at Fordham University and research in the use of machine methods in the handling of mass statistics.

I have a chart (table 1) to which I would like to refer, Mr. Chairman, which summarizes these weapon sizes. As I indicated, there were 263 weapons used for a total weight of 1,446 megatons; 60 of these weapons were 10-megaton size for a total of 600. This chart illustrates the distribution of the other weapon sizes. There were 74 of 8 megatons for a total of 592, and, as you will see, there was a large weight in the higher weapons of 8 and 10 megatons reducing to 37 of the 2-megaton weapons and 48 of the 1 megaton, for a total attack of 1,446 megatons.

The next chart (table 2) shows the distribution by target; 111 of the targets were Air Force installations. Total weight 645 megatons. The size of the weapons used on Air Force installations varied; 71 of the targets were critical target areas. By this we mean concentrations of population and industry. They contain about 68 million of the country's population. One hundred and ten weapons were used against these areas for a total weight of 567 megatons. I will leave this chart up while I talk further, Mr. Chairman.

(The charts referred to are as follows:)

TABLE 1.—*Weight of the attack*

Size of weapon (megatons)	Number used	Weight of attack (megatons)
10	60	600
8	74	592
3	44	132
2	37	74
1	48	48
Total	263	1,446

TABLE 2.—*Targets of the attack*

Number and type of target	Number of weapons	Weight (megatons)
111 Air Force installations	111	645
71 Critical target areas	110	567
21 AEC installations	21	168
12 Army installations	12	24
5 Navy installations	5	28
4 Marine Corps installations	4	4
224, total	263	1,446

Representative HOLIFIELD. Mr. Quindlen, I think it would be well to bring out at this point the fact that the two bombs used over the Japanese cities were approximately 20,000 tons of TNT equivalent.

Mr. QUINDLEN. Yes, in that general area.

Representative HOLIFIELD. In that general area?

Mr. QUINDLEN. Yes.

Representative HOLIFIELD. So, when we talk about a megaton, we are talking about a million tons, and then we have to, in our mind, compare that with 20,000 tons which destroyed a city of some 100,000 inhabitants in Japan.

Mr. QUINDLEN. Yes, sir; that is true.

About 39 percent of the weapons used were used against the industrial and population areas, about 12 percent were used against Atomic

of the subcommittee by Lt. Gen. James M. Gavin, U.S. Army, retired, former Deputy Chief of Staff for Research and Development.

DEAR MR. HOLIFIELD: I have examined the theoretical nuclear attack pattern that is to be considered by your committee in the hearings beginning June 22, 1959. I consider your assumptions to be entirely realistic and well within the capabilities of a potential aggressor.

JAMES M. GAVIN,
Lieutenant General (Retired).

Are there any questions of the witness?

If not, you are excused, sir.

Mr. QUINDLEN. Thank you, sir.

Representative HOLIFIELD. Our next witness will be Dr. Frank Shelton, Technical Director, Defense Atomic Support Agency of the Department of Defense. Dr. Shelton will give a presentation of the effects of the different-sized weapons used.

STATEMENT OF DR. FRANK SHELTON,[1] TECHNICAL DIRECTOR, DEFENSE ATOMIC SUPPORT AGENCY, DEPARTMENT OF DEFENSE

Dr. SHELTON. Mr. Chairman, it is a pleasure to appear before the committee. I have a few figures that we will have to put on the easel, but I will begin because they are used partially down in the text.

The effect of a nuclear war is the sum of the effects of the weapons employed against the individual targets. The individual weapon's effects thus form the building blocks for the sum of the effects. It is generally true that the effects of blast, thermal radiation, and prompt nuclear radiation (emitted directly from the exploding bomb) will not overlap the same areas with important effects unless two or more bombs are detonated rather close together on a single target. Local fallout from surface bursts is about the only weapon effect that can be expected to have overlapping effects from one bomb to another and this is especially true in the downwind directions.

Thus, the total damage to the country from blast, thermal radiation, and prompt nuclear radiation is essentially the sum of the individual effects on the individual targets.

In the case of fallout one often has to add the effects of one bomb on another in their common fallout areas. Finally, worldwide fallout is the sum of each of the individual weapons contribution.

In summarizing the various effects, I would like to draw into perspective, in some small measure, the relatively large areas and are also likely to be involved by the other effects. As an example, the lethal fallout area giving about 700 rem in 48 hours——

Representative HOLIFIELD. Will you please explain rem?

Dr. SHELTON. Can I hold that? It is in the text, if you will allow me to wait until we get to that point.

Representative HOLIFIELD. All right.

Dr. SHELTON. An accumulation of about 700 rem in 48 hours for an unshielded person can be expected to occur over about 1,500 square

[1] Technical director of the Defense Atomic Support Agency. He has been active in the atomice energy field since 1952. During the spring of 1955, he served as technical adviser to the military effects test group at Operation Teapot, and in 1953 participated in Upshot-Knothole. Dr. Shelton was born in 1924. He received his bachelor of science, master's and doctor of philosophy degrees, all in physics, from the California Institute of Technology. Prior to joining the Defense Atomic Support Agency, Dr. Shelton was with the Sandia Corp. in the weapons-effects field.

miles from a 10 megaton surface burst (50 percent fission); that is, an area that could be about 100 miles long and about 17 miles at the maximum width.

Few people appreciate the fact that, for the same bomb, second degree burns on the exposed face and hands and the ignition of fine kindling fuels can encompass an area of about 25 miles radius or about 2,000 square miles in the immediate vicinity and perhaps dense population of the target area. That is, this thermally affected area could be substantially larger than that of the lethal fallout area. And, if there is some shielding of personnel in the downwind fallout areas, the thermal effects area would certainly be the larger of the two.

Fallout and its potentially lethal areas are imporant, but so are the areas of the other effects; the pendulum of interest has swung to fallout and there is some tendency to overlook the very important other effects. Your expert witnesses in blast, thermal radiation, and prompt nuclear radiation also have an important part of the story. The results produced in Japan by the two nominal yield bombs were from only blast, thermal radiation and prompt nuclear radiation. There was no local fallout involved in the nearly 400,000 casualties in the tale of those two cities.

In discussing the effects of a large yield detonation it seems pertinent to:

I. Describe what happens when a nuclear detonation occurs; that is, how the blast, radiant heat, prompt nuclear radiation, and fallout are produced.

II. Next, I would like to describe very briefly the main differences in an airburst and a surface burst. I realize that the hypothetical attack assumed for these hearings utilizes surface bursts; however, a few words about airbursts does not appear out of place.

III. Finally, I would like a summarize the various weapons effects by relating the distances at which certain effects can be expected to produce a given level of damage to man or structures.

I. DESCRIPTION OF A NUCLEAR EXPLOSION

At the moment of detonation, a tremendous amount of energy is released in an extremely short time and small space. This rapid release of energy heats the bomb material and surrounding air to temperatures of several hundred thousand degrees, forming a luminous sphere of hot gases called the "fireball." The expansion of the air heated by the nuclear detonation causes the formation of a shock wave. At rather close distances to the burst, the shock wave is extremely strong and shocks the air to conditions such that it is radiant—that is, glows—and the fireball continues to grow in size. About 35 percent of the total energy of the explosion is given off as radiant thermal energy (see fig. 1) or heat, in essentially the same way that the sun radiates heat, although in the case of a bomb it is delivered very rapidly.

overpressure produces a crushing effect on the structure as it engulfs it. Since the blast wave is also a mass of air in motion at very high velocity, it exerts a dynamic force on the structure, tending to translate it in much the same manner as a hurricane wind. Such structures as multistory brick apartment houses are quite vulnerable to the blast wave. (See fig. 4.) All such structures would be destroyed, collapsed, within a radius of 7 miles from ground zero for a 10-MT weapon; that is, one having a total energy equivalent of 10 million tons of TNT.

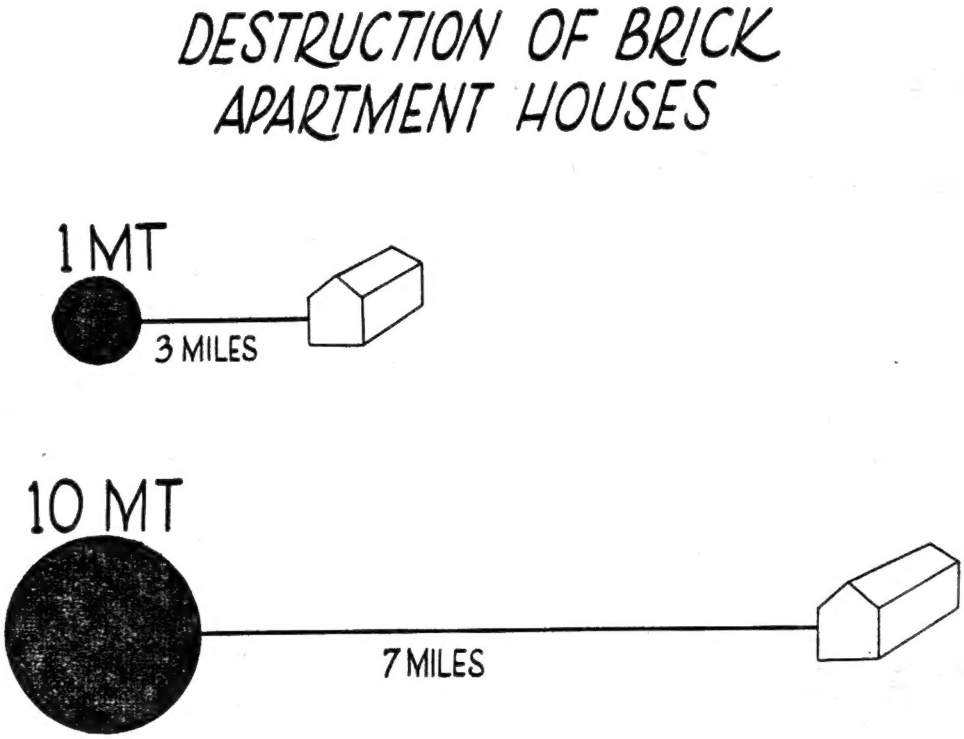
If we decrease the yield by a factor of 10, we have a 1-megaton weapon. For this yield, all such structures within a radius of over 3 miles from ground zero would be destroyed for a surface burst. Thus, a factor of 10 in yield will change the radius of blast damage by a factor of little more than 2.

Senator HICKENLOOPER. Just a moment, Mr. Chairman.

Representative HOLIFIELD. Senator Hickenlooper.

Senator HICKENLOOPER. I am having a little trouble here with the verbiage. You say if we decreased the yield by a factor of 10, we have a 1-megaton weapon. Then this sentence——

FIGURE 4



Dr. SHELTON. It refers to the previous sentence. We decrease the 10 megatons to 1 megaton.

Senator HICKENLOOPER. I understand you decrease the 10 to 1, but then this sentence.

For this yield, all such structures within a radius of over 3 miles from ground zero would be destroyed for a surface burst.

As I take it that statement says everything over 3 miles beyond the center of the surface burst would be destroyed whether it was a hundred miles away or 200 miles away.

Dr. SHELTON. I can understand the problem there.

Senator HICKENLOOPER. We are dealing with a very technical and with a very, if I may use the word, frightening subject here, and I am concerned with the literal statements that are made.

(The information referred to follows:)

Thermal Ignition of Framehouses

There is some uncertainty as to whether or not persistent ignition can occur to well-painted good wood, such as the type of siding that is used on framehouses, under the conditions of a nuclear explosion. The following quotations are taken from "The Effects of Nuclear Weapons," and the referenced paragraph numbers are given:

7.62 "Wood is charred by exposure to thermal radiation, the depth of the char being closely proportional to the energy received. For sufficiently large amounts of energy, wood in some massive forms may exhibit transient flaming, but persistent ignition is improbable under the conditions of a nuclear explosion. However, the transitory flame may ignite adjacent combustible material which is not directly exposed to the radiation. * * *"

7.93 "From the evidence of charred wood found at both Hiroshima and Nagasaki, it was originally concluded that such wood had actually been ignited by thermal radiation and that the flames were subsequently extinguished by the blast. But it now seems more probable that, apart from some exceptional instances, such as that just described, there was no actual ignition of the wood. The absorption of the thermal radiation caused charring in sound wood but the temperatures were generally not high enough for ignition to occur. Rotted and checked wood and excelsior, however, have been known to burn completely, and the flame is not greatly affected by the blast wave."

7.82 "The fact that accumulations of ignitable trash close to a wooden structure represent a real fire hazard was demonstrated at the nuclear tests carried out in Nevada in 1953. In these tests, three miniature wooden houses, each having a yard enclosed with a wooden fence, were exposed to 12 calories per square centimeter of thermal radiation. One house, at the left, had weathered siding showing considerable decay, but the yard was free from trash. The next house also had a clean yard; and, further, the exterior siding was well maintained and painted. In the third house, at the right, the siding, which was poorly maintained, was weathered, and the yard was littered with trash."

7.38 "The state of the three houses after the explosion was as follows: The third house, at the right, soon burst into flame and was burned to the ground. The first house, on the left, did ignite but it did not burst into flame for 15 minutes. The well-maintained house in the center with the clean yard suffered scorching only. * * *"

Thermal effects comparable to those existing at these three houses would occur at 13 miles from a 10-megaton burst and at 6 miles from a 1-megaton burst.

Dr. Shelton. Thus not only may your house be blown down, but it may be on fire due to the ignition of curtains or inflammable materials outside the house. There is a chance of a very large general fire throughout the area, a conflagration or fire storm. A fire storm existed at Hiroshima and lasted about 6 hours.

Representative Holifield. Will you explain for the record what a fire storm is?

Dr. Shelton. In the case of Hiroshima, the fire storm was a general burning in the area of the target with air sweeping in, feeding the fire from all sides, and the heat rising up, a great smoke pall moving upward and out of the general area, so that there was a mass circulation of air. In other words, new fresh air was coming in to feed the fire. It burned for about 6 hours. At the edge of the fire storm there were winds like 30 and 40 miles an hour, and those generally subsided and became rather small and variable at the end of 6 hours.

The reason I mention the fire situation is that a fire that burns for times like 6 hours, raging in an area, even shelters there would have to

direction should start about a half hour after the burst. In other words, you have about a half hour, but I don't know what you are going to do with it. You have a half hour if you want to use it before the fallout starts. 8 miles downwind from 10 megaton G.B.

Chairman ANDERSON. I am going to get under a shower. Somebody else can do what he wants.

Dr. SHELTON. All right. The fallout will start and it won't be very intense at a half hour, and it will build up to a peak and it will be about 3,000 roentgens per hour or more at the end of the hour, if you are about 10 miles downwind. It is going to peak and be about 3,000 roentgens per hour outside on the level ground. You could not stand more than about 15 minutes of that radiation until you will probably be incapacitated, deathly sick, and terminate in death.

Chairman ANDERSON. Thank you.

3. Worldwide fallout

Dr. SHELTON. Moving on from the local fallout it is certainly pertinent to discuss the worldwide fallout in this particular situation. I would like to say a few words about the worldwide fallout. If you remember, the large particles of radioactive debris were deposited locally, and the small minute particles from the explosion that enter the stratosphere spread more or less uniformly around the earth at a given latitude and fall to earth very slowly. As I said before, about 50 percent per year will come down to the ground. Here are those numbers that we have been discussing and let me say them once again. Here we have material away up in the stratosphere. What is going to happen to it? In 7 hours its intensity is down to one-tenth of the activity that we had at 1 hour. After 2 days it is down by a factor of a hundred. Two weeks it is down by a thousand. Three months it is down by 1 over 10,000. From this it is pretty apparent that the worldwide fallout that is coming down at a rate of about one-half per year, only contains those elements that are long lived like strontium 90, cesium 137, and carbon 14. They are the only ones that are left with any appreciable activity. To say what is happening in worldwide fallout for our hypothetical war situation, let me revert back to what we now know.

We expect 5 to 10 micromicrocuries of strontium 90 per gram of calcium to be the ultimate average value in the bone of man for the north temperate latitudes as a result of testing 90 megatons of fission yield. We know the effects for 90 megatons. Let us say what we are going to get for a thousand megatons. You get about 10 times as much. So you get 50 to 100 micromicrocuries per gram of bone calcium. I think in our war assumptions we have 2,000 megatons of fission products. So one would expect to get something like 200 micromicrocuries, which is a little larger than the maximum permissible concentration standard for the population as a whole, but which is a number, I think, that we recognize to be rather conservative. Similarly, let us talk about the genetic dose for a moment.

In the Northern Hemisphere the genetic dose from past testing has been about 0.05 rem over a 30-year genetic time period. So in the war we would expect about 0.5 rem per thousand megatons of fission yield in the weapons. We have 2,000 in our assumed case. So we would expect about one rem genetic dose. This is less than the

person. The degree of incapacitation depends on the parts of the body exposed and the amount of energy received. For example, second degree burns of the hands are those which cause blistering, and are most painful, and will pretty effectively prevent work by that individual, and second degree burns of the eye area will certainly make one rather ineffective. For 1-megaton surface bursts, a person exposed within 9 miles of ground zero and with no shielding can be expected to receive second degree burns on any bare skin exposed directly to the bursts. For a 10-megaton weapon this range would be not quite three times as large in distance, about 25 miles away from a 10-megaton bomb. A person with exposed skin could expect to receive blistering, and second degree burns.

Representative HOSMER. In relation to protection against that, the areas that were clothed, would they receive any substantial damage?

Dr. SHELTON. The clothing area at this distance should minimize the burn to a blistering or sunburn type and not a blistering burn. Under clothing at these distances, the skin would have some protection and it would be like a sunburn, but not blistering. At closer distances, you can get second degree burns under clothing.

As another example, a person standing out in the open at 25 miles from a 10-megaton burst will receive blisters an all exposed skin. These second degree burns are the most difficult type to treat clinically. I am sure you will have an expert witness to cover this quite thoroughly.

Representative HOSMER. The protection factor on this type of thing is minimal.

Dr. SHELTON. Yes. All you need is something opaque between you and the bomb, any type of material, and the thermal hazard goes away down.

Representative HOLIFIELD. Dr. Shelton, I note there has been no discussion of the immediate neutrons.

Dr. SHELTON. They were included and integrated into the dose received from the prompt radiation. That last chart still on the floor showing the initial radiation resulting in probable death, has prompt gamma and prompt neutron added together into that dose. It does not matter what does it, if it kills you, and its effect on the tissue are very much the same.

5. Blast

Blast overpressure is itself not a very significant casualty agent. About 100 p.s.i. is required to have a significant effect of ruptured eardrums, for instance, and nuclear radiation, thermal radiation and fallout will almost certainly produce casualties where 100 p.s.i. can reach a man. However, the secondary effects and injuries caused by crumbling buildings, flying debris and translation of man himself are certainly very significant. Extensive blast injury can be expected at distances at which brick apartment houses collapse, and those distances were 7 miles from ground zero for a 10-megaton burst, and a little over 3 miles for a 1-megaton burst.

I believe you have a blast biology witness, Dr. White, in the later days, and I am sure he will tell you about the hazards of flying debris and in particular the hazard of flying glass. I would expect exten-

sive window damage at 25 miles from a 1-megaton burst, and it would be an extreme hazard out to about 7 miles. Don't stand behind windows in an attack. First you will get burned and then you will have fine glass splinters driven into you very deeply within distances like 7 miles from a 1-megaton burst.

Representative HOLIFIELD. Every schoolroom in the United States has tremendous expanses of glass.

Dr. SHELTON. Yes, sir.

Representative HOLIFIELD. I think this is a very important point you are bringing up, and I am sure it will be gone into in more detail when the blast witness appears before us.

Dr. SHELTON. Yes. Glass in any disaster like the Texas City disaster is one of the primary materials found in the normal home which can result in blinding and all other types of effects due to the flying small splinters of glass.

My long acquaintance and friend, Dr. White, will fully expound on the hazard of debris, and particularly flying glass.

IV. SUMMARY OF EFFECTS FOR NUCLEAR WEAPONS FOR 1 AND 10 MEGATONS

To summarize the effects of nuclear weapons, they are blast, which is primarily a damaging agent to inanimate objects such as buildings, and it does produce flying debris which is a hazard to man.

The cratering effect results in the destruction of even deep underground structures. Thermal radiation damages both humans and combustible structures and materials. Nuclear radiation, including both the initial and the local residual fallout are primarily hazards to man and animals and can deny man the use of inaminate objects. For reference, I have included in table 1 the effects that I have been discussing for the last hour or so.

TABLE I.—*Summary of effects of the assumed nuclear weapons 1 to 10 megatons*

	1 megaton	10 megatons
A. Inanimate objects:		
1. Crater (dry soil)	Radius, 650 feet Depth, 140 feet	Radius, 1,250 feet. Depth, 240 feet.
2. Brick apartment houses collapse	Radius, 3 miles	Radius, 7 miles.
3. Ignition of light kindling materials	Radius, 9 miles	Radius, 25 miles.
B. Man:		
1. Blast injury (flying debris)	Radius, 3 miles Area, 28 square miles	Radius, 7 miles. Area, 150 square miles.
2. 2d degree burns on bare skin	Radius, 9 miles Area, 250 square miles	Radius, 25 miles. Area, 2,000 square miles.
3. Initial nuclear radiation (700 r.e.m.).	Radius, 1.5 miles Area, 7 square miles	Radius, 2 miles. Area, 12.5 square miles.
4. Fallout, 15-knot winds (450 r.e.m. in 48 hours, no shielding).	40 miles downwind, 5 miles crosswind. Area, 200 square miles	150 miles downwind, 25 miles crosswind. Area, 2,500 square miles.

Moving to man, let us just repeat again, blast injury, due to flying debris, occurs out to about 3 miles for a megaton weapon, and about 7 miles for a 10-megaton weapon. The areas there are about 28 square miles and 150 respectively. The burn area is a very large area, as you see, for a 10-megaton burst, about 2,000 square miles on clear days, or when the bomb thermal is easily seen. Fallout; in this case

450 rem in 48 hours, and no shielding, occurs in an area of about 2,500-square miles for a 10-megaton weapon.

Running down the columns, you notice that 10 megatons is 10 times the energy release of 1 megaton. But notice that the effects only reach out sometimes a factor of two, sometimes a factor of three, seldom ever a factor of four for the larger yield burst. A 10-megaton yield does not reach out to 10 times the distance. The distances are rather slow functions of yield, usually a factor of two, sometimes a factor of three. This is the variation in distance of a given effect from 1 to 10 megatons.

I did not feel that in the testimony I should cover two, three, and eight megatons. They can be interpolated in between the distances given and the uncertainties of effects are probably larger than warranted by exact mathematics for the other yields.

Representative HOLIFIELD. It occurs to me, Dr. Shelton, in the responses to Mr. Hosmer's questions, and other questions from members that you might want to prepare a statement in regard to this rate dose. You might include in that the factors of difference between, let us say, 10, 100-kiloton weapons, and 1 megaton weapon and such other pertinent information as you think would clear up and remaining doubts. We realize that we cannot cover the whole field, but we will try to do the best we can.

Dr. SHELTON. I will certainly do that, sir. (See table I, p. 41.)

Representative HOLIFIELD. Are there any questions of Dr. Shelton? If not, there is one question I would like to ask you, Doctor. Is it not true that if human beings are in the blast area, it is not only the external pressure upon the human individual's body which is dangerous, but also the human being himself becomes a flying missile, and is propelled through the air until he does strike an inanimate structure?

Dr. SHELTON. That is precisely right, sir. The body is able to withstand overpressures quite well. It is the flying debris, the translation of the man himself in the hurricane-like winds that accompany the bomb. It is this sort of thing that always accompanies the blast and produces the blast casualties.

Representative HOLIFIELD. Did you have anything else to add?

Dr. SHELTON. No, sir.

Representative HOLIFIELD. Thank you very much, Dr. Shelton. It might be well for the record to show that Dr. Shelton is Technical Director of the Defense Atomic Support Agency. He has been active in the atomic energy field since 1952. During the spring of 1955 he served as technical adviser to the military effects test group at Operation Teapot, and in 1953 participated in Upshot-Knothole. He has also participated in Operation Redwing in 1956, Operation Plumbbob in 1957, and Operation Hardtack in 1958. Dr. Shelton was born in 1924. He received his bachelor of science, master's, and doctor of philosophy, all in physics from the California Institute of Technology, and prior to joining the Defense Atomic Support Agency (formerly the Armed Forces Special Weapons Project), Dr. Shelton was with the Sandia Corp. in the weapons effects field.

Thank you very much for your testimony this morning. We plan to have our next witness at 2 o'clock, Mr. Charles Shafer, from the Office of Civil Defense Mobilization.

The meeting is adjourned until 2 p.m.

(Thereupon at 12 m., a recess was taken until 2 p.m., the same day.)

AFTERNOON SESSION

Representative HOLIFIELD. The committee will be in order.

This afternoon we open the session with testimony from Dr. Charles Shafer, Office of Civil Defense and Mobilization.

Representative HOLIFIELD. I might note that Mr. Shafer has been meteorologist for the U.S. Weather Bureau from 1940 to 1957. He served with the Air Force during the war. He was in the FCDA and now in the Office of Civil Defense and Mobilization. He heads up their meteorological services in the fields of chemical, biological, and radiological defense. He testified before this committee in 1957.

Mr. Shafer, will you please come forward.

I will say to the members of the committee that copies of Mr. Shafer's presentation are a little slow in getting here. They will be in a little later and they will be distributed as soon as they arrive.

TESTIMONY OF CHARLES K. SHAFER,[1] DIRECTOR, METEOROLOGICAL OFFICE, OFFICE OF CIVIL AND DEFENSE MOBILIZATION

Mr. SHAFER. Mr. Chairman and members of the committee, may I first correct the record with regard to the title. It is mister and not doctor. I wish it were, but it is not.

This study, requested by the committee, was undertaken in order to indicate the extent and intensity of close-in radioactive fallout which might spread across the United States after a specific nuclear-attack with the meteorological conditions for a given day.

This presentation will also indicate the effects of the attack on dwellings with regard to blast and thermal factors and with regard to fallout.

To better understand the development of the fallout situation, we shall first examine the attack in greater detail. Chart No. 1 indicates the attack pattern which was developed and provided by the committee as a basis for the study. Each circle such as at Syracuse, Binghamton, Evansville, Waco, Great Falls, et cetera, represents the surface detonation of a 1 megaton nuclear weapon. There are 48 of these weapons.

---

[1] Born: May 26, 1918.
Undergraduate work—New York State College at Albany, N.Y.
Graduate work—College of Engineering, New York University.
Has participated in weapons detonations during Plumbbob and Hardtack, performing: (a) Aerial and surface monitoring; (b) fallout prediction; (c) dose-depth and dose-distance relationships; (d) shelter evaluation.
1940–57, Meteorologist with U.S. Weather Bureau.
(a) On loan to U.S. Air Force during World War II (Wright-Patterson area).
(b) On loan to the United Nations for meteorological research, 1948–49.
(c) On loan to CAA and assigned at Athens, Greece, to plan rehabilitation of the Greek Weather Service, 1952–54.
(d) On loan to FCDA to assist in radiological fallout problem, 1955–57.
(e) Transferred to FCDA (now OCDM) in 1957 to head up their meteorological services in the fields of chemical, biological, and radiological defense.

Each square such as at Jacksonville Navy Base, Redstone Arsenal, Hartford, Minot, Alamogardo, Eglin Air Force Base, et cetera, represents the surface detonation of a 2 megaton nuclear weapon. There are 38 of these.

Each triangle such as at New Haven, Worcester, Toledo, Grand Rapids, Abilene, San Bernardino, et cetera, represents the surface detonation of a 3 megaton nuclear weapon. There are 44 of these.

Each half circle such at as Patrick Air Force Base, Cape Carnaveral, Savannah River, Boston, Rochester, Memphis, Oklahoma City, Denver, Berkeley, et cetera, represents the surface detonation of an 8 megaton nuclear weapon. There are 74 of these.

Each star such as at Limestone Air Force Base, New York City, Philadelphia, Baltimore, Washington, Pittsburgh, Detroit, Chicago, St. Louis, Kansas City, Dallas, Los Angeles, San Francisco, Portland, Seattle, et cetera, represents the surface detonation of a 10 megaton nuclear weapon. There are 60 of these.

By States, California has the greatest megatonnage, 19 weapons, 124 megatons. Texas has the greatest number of weapons, 24 weapons, 112 megatons. In both States the attacks are primarily on Air Force bases.

There is a marked concentration of weapons along the city complex from Washington to Boston. For example, there are 28 megatons in the Washington area, 22 in Baltimore, 20 on Philadelphia, 20 on New York City, and 22 on Boston. Actually along this line from Washington to Boston there are 275 megatons. Other areas of weapon concentration are Detroit, Chicago, and Los Angeles with 20 megatons each and the San Francisco-Oakland Bay area with 38 megatons.

The following five maps (Charts 2–6) will indicate our estimate of what the fallout situation would be across the United States 1 hour after the nuclear attack, 7 hours, 2 days, 2 weeks, and 3 months. The maps will also show our estimates of the accumulated, outside, unsheltered radiation doses at various points along the fallout patterns.

These fallout estimates are developed from the stylized dose rate patterns in the "Effects of Nuclear Weapons." The stylized dose rate patterns in this publication are based upon monitored data from multimegaton detonations in the Pacific Proving Grounds and from kiloton detonations in Nevada and the Pacific. At any specfic point in these fallout areas, the dose rate values are subject to the same uncertainties as are all quantitative fallout forecasts. However, they do have sufficient accuracy for planning purposes, i.e., sufficient accuracy to indicate the extent and intensity of the fallout problem for which we must plan survival actions.

Further, as instructed by the committee the weapon design has been assumed to be 50 percent fission–50 percent fusion. It is further assumed that about 80 percent of the radioactivity produced will come down as close in fallout during the first 2 days postattack. The meteorology selected for the preparation of the fallout charts is October 17, 1958.

On this day the average wind speed in the deep column of the atmosphere from 60,000 feet to the surface on the earth, was about 60 miles per hour in the upper Great Lakes region and the northern plains. It averaged 40 miles per hour over New England, the Middle

tion. This is one meteorological condition, and one attack pattern.

Shall I proceed?

Representative HOLIFIELD. Proceed, Mr. Shafer.

Representative WESTLAND. May I ask one further question?

Representative HOLIFIELD. Mr. Westland.

Representative WESTLAND. How did you happen to choose the setup that you did?

Mr. SHAFER. This attack pattern, sir.

Representative WESTLAND. Yes.

Mr. SHAFER. It was provided by the committee.

Representative HOLIFIELD. The attack pattern, as shown in the handouts, was established as a reasonable type of attack after a great deal of consultation on the part of the members of the subcommittee and the staff with people who are experts in the field. This study, for instance, is approximately 1,500 megatons on the United States whereas I believe a previous study by the Civil Defense Administration went as high as 2,500.

Is that not true, Mr. Shafer?

Mr. SHAFER. We have studied attacks of this size and other sizes, sir.

Representative HOLIFIELD. Can you give at this time the different operation alerts and the amounts used in those attacks from memory?

Mr. SHAFER. Not very well from memory. I believe Opal 57 was about 384 megatons, and Opals 58 and 59 about 675 megatons.

Representative HOLIFIELD. There was one at 2,500.

Mr. SHAFER. This was not an operation alert. This was a special internal exercise which we called Sentinel.

Representative HOLIFIELD. Was the 2,500 study effects made public?

Mr. SHAFER. Yes, to this particular committee in 1957, sir.

Shall I proceed, sir?

Representative HOLIFIELD. Yes.

Mr. SHAFER. This table shows the effects of the attack on dwellings within the United States. It indicates the numbers of units receiving severe, moderate, and light blast damage. Further, it shows the total units outside the blast areas which would be under fallout intensities exceeding 3,000 roentgen-hours; 1,000 to 3,000 roentgen-hours; 100 to 1,000 roentgen-hours and less than 100 roentgen-hours when normalized to H+1 hour.

Effects on dwelling

	Units
Blast effects:	
Severe damage	11,800,000
Moderate damage	8,100,000
Light damage	1,500,000
Fallout effects:	
Greater than:	
3,000 r/hr	500,000
1,000–3,000 r/hr	2,100,000
100–1,000 r/hr	10,400,000
Less than: 100 r/hr	11,700,000

It should be noted that 11.8 million dwellings would suffer severe damage—to the extent that they would not be salvageable. This is approximately one-fourth of the dwellings in the United States. And an additional 8.1 million dwellings or about 17 percent of the national

total would suffer moderate damage and would have to be vacated for major repairs. Further, 1.5 million dwellings or about 3 percent would suffer light damage and could be repaired without being vacated. This totals 21.4 million dwellings damaged.

Representative HOLIFIELD. How does that rate relate to the total number of dwellings?

Mr. SHAFER. This is a little less than half, sir.

Representative HOSMER. Give us the number.

Mr. SHAFER. 46.1 million dwellings total in the United States and this is 21.4 million dwellings damaged, a little less than 50 percent. Let us say 45 percent.

Approximately 500,000 dwellings, outside the areas of blast damage, would be affected by fallout intensities exceeding 3,000 r/hr. normalized to H+1 hour. These are the red shaded zones on the fallout maps. The homes in these zones would have to be evacuated and abandoned for probably a year, perhaps longer.

About 2.1 million dwellings, outside the areas of blast damage, had fallout intensities varying between 1,000 and 3,000 r/hr. when normalized to H±1 hour. These are the blue shaded areas on the fallout maps. The homes in these zones would have to be evacuated and abandoned for a period for several months to perhaps a year in some instances. Actually, the period of abandonment would depend upon this effectiveness of decontamination and the rapidity of radiological decay. However, this subject is scheduled for discussion later by another group.

Approximately 10.4 million dwellings, outside the areas of blast damage, had fallout intensities varying between 100 and 1,000 hr. when normalized to H+1 hour. These are the yellow shaded zones on the fallout maps. If major decontamination efforts were undertaken most of the homes in these yellow areas could be made available for living by 60 days' postattack.

About 11.7 million dwellings, outside the areas of blast damage, had fallout intensities less than 100 r./hr. when normalized to H+1 hour. These are the green areas and unshaded zones on the fallout maps. Although a serious radiation problem would exist in the inner portions of the green shaded zones, most of the homes in these areas could become available by 2 weeks' postattack.

This totals 24.7 million dwellings outside of the area of blast damage affected by fallout.

Let us look at this chart in a little more detail to determine how serious the problem would be. This plus this, that is the homes beyond repair, the homes vacated for major repairs, plus those which would be denied to us for a period of months to possibly a year because of fallout, total about 22.5 million units; or approximately 50 percent of the dwelling units across the United States would be denied use for 60 days to some indefinite period of time.

This completes my formal presentation, sir. If you have questions I will be very happy to try to answer them.

Representative HOLIFIELD. Please stand by for questions.

Are there any questions?

Representative HOSMER. Mr. Chairman, I don't have questions at this point but the witness has mentioned on two or three occasions

TESTIMONY OF LESTER MACHTA,[1] U.S. WEATHER BUREAU

Dr. MACHTA. Thank you, Mr. Chairman.

I think we are all aware of the fact that from our past experience all atomic tests which have local fallout also produce worldwide fallout. There are two main problems in computing this worldwide fallout. First, we must know how much radioactivity is available for dispersal and, second, we must know how it is distributed. It is the purpose of this discussion to describe the assumptions used in preparing the maps showing the worldwide fallout. In addition, I will describe, in words, the fate of the radioactive carbon 14 created by a nuclear war.

First the production of radioactive debris will be presented.

For purposes of illustration and because of its familiarity, we shall deal with strontium 90 fallout. Later, we can apply the results to other long-lived radionuclides.

The attack on the United States of approximately 1,500 megatons is augmented by 2,500 megatons elsewhere in the world for a total of about 4,000 megatons. Fifty percent of the energy from each weapon was assumed to be derived from fission, for a total of 2,000 megatons of energy equivalent of fission products. Each megaton of fission energy creates 100,000 curies of strontium 90. Thus, the 2,000 megatons energy equivalent of fission produces 200 million curies of strontium 90. These curies are divided as follows: 80 percent is deposited in local fallout, 15 percent in stratospheric fallout and 5 percent in tropospheric fallout. About 20 percent of the 200 million curies are available for worldwide dispersal.

In the United States, the local fallout deposition has been calculated by OCDM based on the AFSWP idealized model. Since estimates of the total (local plus worldwide) as well as the worldwide strontium 90 fallout are desired in the United States, it is necessary to convert the external dose to the strontium 90 which is associated with the gamma emitting fission products. We assume that 1 roentgen per hour at 1 hour is equivalent to 100 millicuries per square mile of strontium 90. This conversion is based on the "Effects of Nuclear Weapons" plus a small correction for shielding of particles in the actual ground since it is not a perfectly smooth surface.

Second, we will distribute the worldwide fallout.

The tropospheric strontium 90 is carried rapidly around the world in a generally west-to-east direction. It spreads in a north-south direction slowly so that the peak fallout is roughly in the latitude of the war area. The stratospheric fallout is deposited entirely in the Northern Hemisphere peaked at about 45° north and tapering off

---

[1] Meteorologist, U.S. Weather Bureau; associated with atomic energy and meteorology since coming to Washington in 1948, now Chief of the Special Projects Section. Born in New York, N.Y., in 1919, graduated cum laude from Brooklyn College in 1939. His meteorological training includes graduate work at New York University (master of arts, 1946) and at Massachusetts Institute of Technology (doctor of science, 1948). During the war he taught meteorology in both a civilian and military capacity for the Air Force. Member of Sigma Xi, Pi Mu Epsilon, the American Meteorological Society, and the American Geophysical Society. Recently been given a gold medal for exceptional service by the Department of Commerce. Publications in the meteorological literature are numerous and, in recent times, include papers on atomic energy and meteorology. Has been a member of many important Government committees, including the Advisory Committee passing on the meteorological safety of tests in Nevada. Has been instrumental in making the worldwide measurement of radioactivity part of the International Geophysical Year program.

We will hear from Dr. Machta again on a paper later on in this series of hearings.

Our next witness is Dr. Terry Triffet, from the U.S. Naval Radiological Defense Laboratory.

I may say for the benefit of the record that the U.S. Naval Radiological Defense Laboratory, which is located at Hunters Point, Calif., is an organization of some 600 scientists and other professional personnel that have been busy working on the problems of weapons effects with particular emphasis in the field of radiation, both on human beings, animals, and different types of physical materials, such as building materials and textiles, and all other types of materials. It is probably the center of our greatest depository for radiological laboratory information.

The managers of the laboratory have chosen Dr. Triffet to give us this part of the presentation. Dr. Triffet, you may proceed.

STATEMENT OF DR. TERRY TRIFFET,[1] U.S. NAVAL RADIOLOGICAL DEFENSE LABORATORY, HUNTERS POINT, CALIF.

Dr. TRIFFET. Mr. Chairman, gentlemen of the committee, I have prepared a formal statement which I would like to submit for the record.

Representative HOLIFIELD. It will be received.

(The statement referred to follows:)

[1] Profession: Research engineer. Date and place of birth: June 10, 1922, Enid, Okla. Parents: R. B. Triffet, Enid, Okla. Married: Millicent McMaster, May 26, 1946. Children: Patricia A. Triffet. Education: B.A. (with honors) Human., University of Oklahoma, 1945; B.S. (with special honors) engineering, University of Colorado, 1948; M.S., engineering, University of Colorado, 1950; Ph. D., engineering, Stanford University, 1957. Professional and honorary societies: APS, ASCE, Society of Rheology, AAAS, Sigma Xi, Phi Beta Kappa, Tau Beta Pi. Work history: 1947–50, instructor, College of Engineering, University of Colorado; 1950–55, rocket research and development, U.S. Naval Ordnance Test Station, China Lake, Calif.; 1955 to present, Head, Radiological Effects Branch, U.S. Naval Radiological Defense Laboratory, San Francisco, Calif. Publications: Several papers and technical reports on effects of radiations on materials, properties of fallout, and radiological effects. Present residence: Palo Alto, Calif.

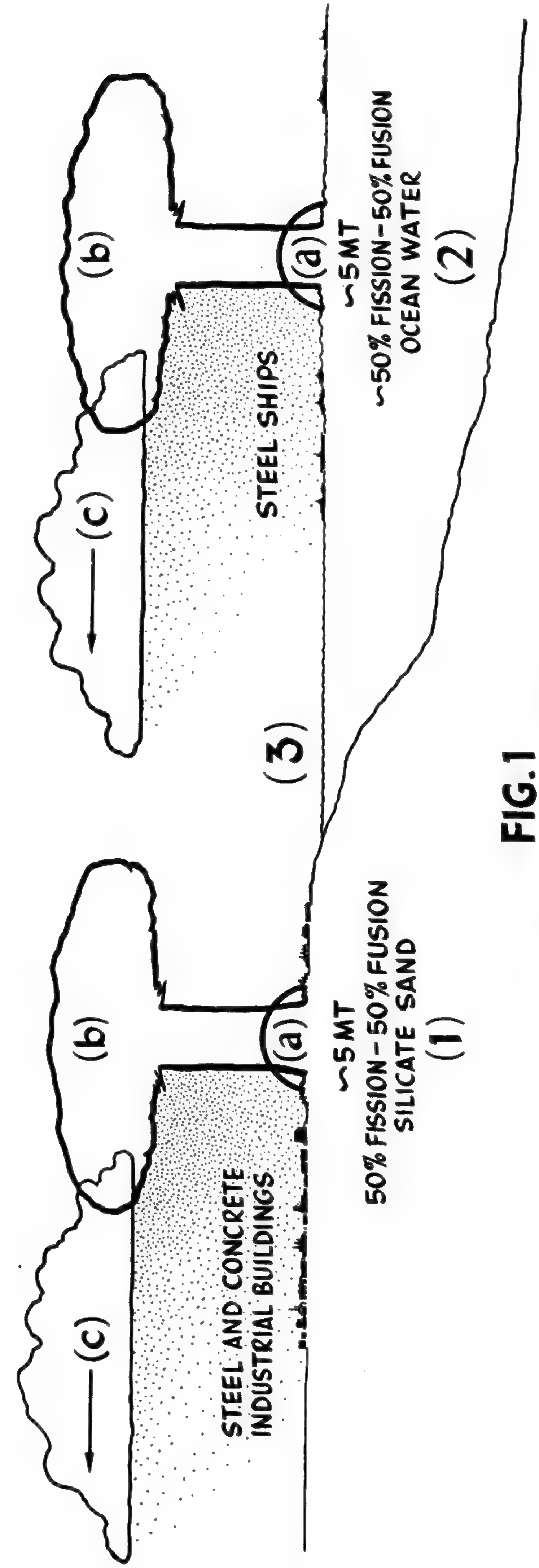


FIG. 1
ASSUMED DETONATION CONDITIONS

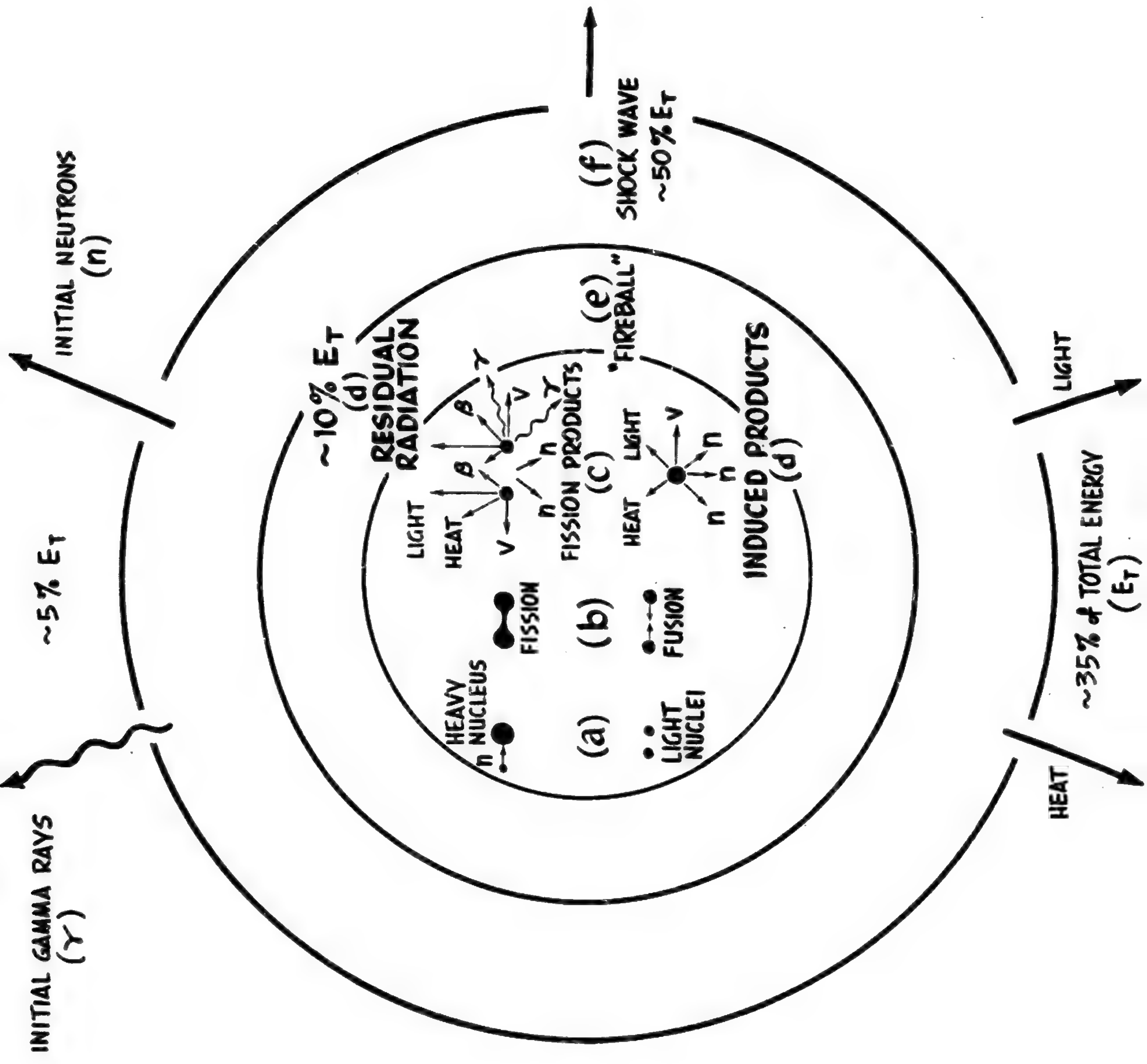
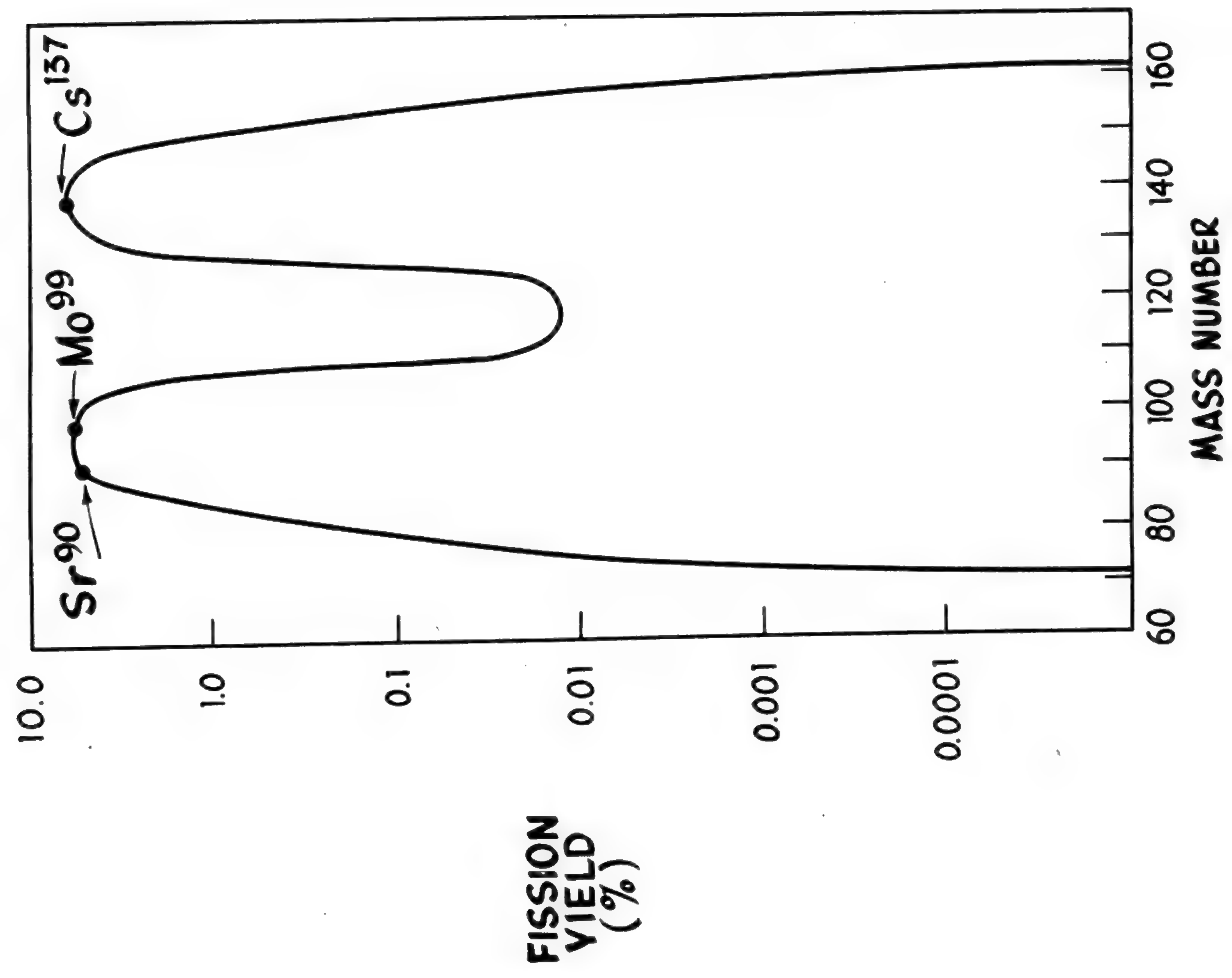


FIG. 2
NUCLEAR
EXPLOSION
PROCESSES

FIG. 3
FISSION PRODUCTS



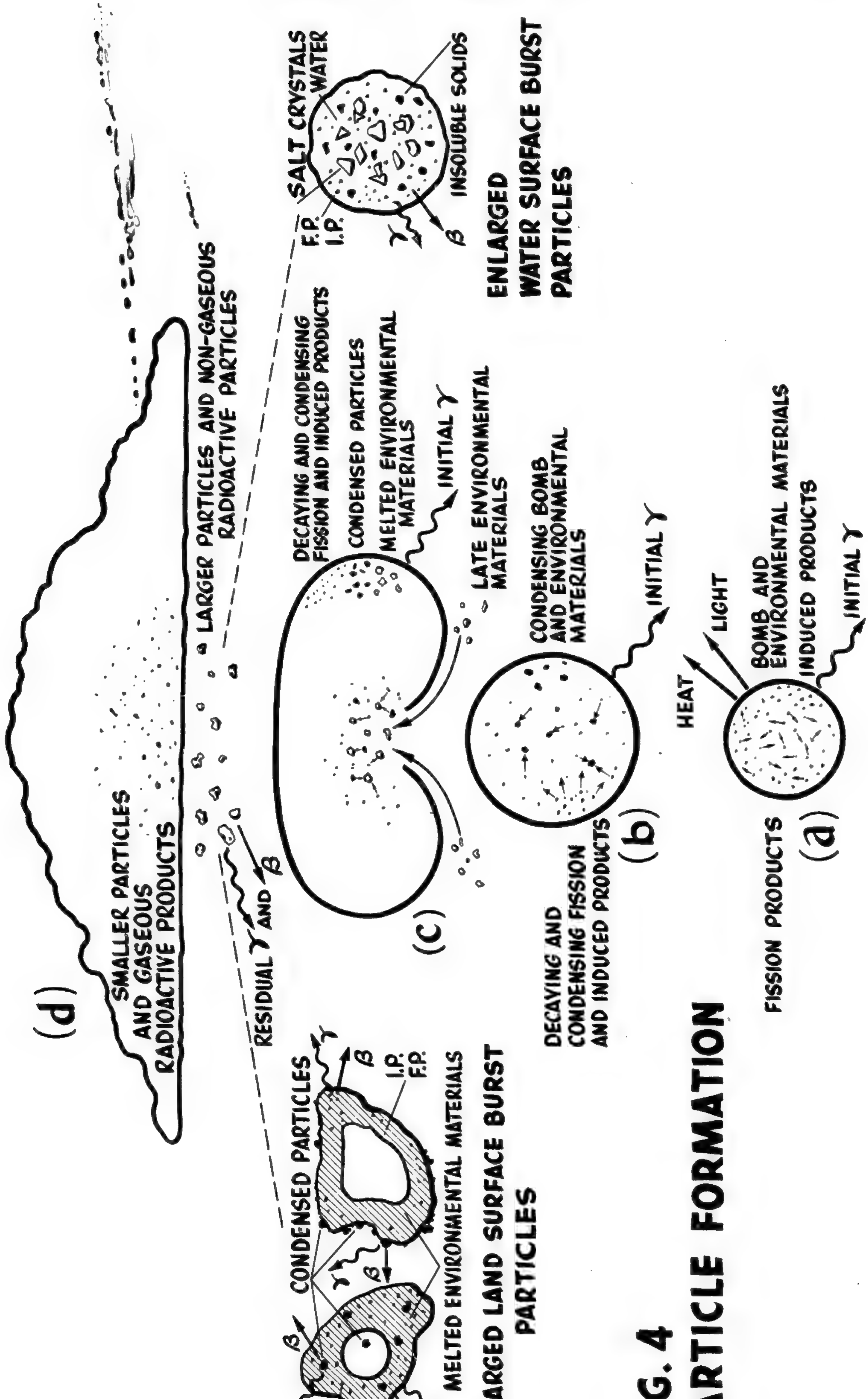


FIG. 4
PARTICLE FORMATION

fractionation of fission products:

~~numbers, in the general temperature range from 2000° to 2800° centigrade. Metals, because of their high boiling points, may provide such particles at early times, while melted soil droplets could provide them at later times.[9] This means that part of the radioactive atoms, particularly those which condense earliest, may become bound to small metallic particles (Figure 4b), which may themselves collide with and become trapped in the larger liquid soil particles (Figure 4c). Some of the remaining atoms will also condense directly on soil particles and other available materials. These larger particles then fall from the cloud to constitute the local fallout (Figure 4d).~~

Part of the radioactive atoms are noble gases, however, and thus do not become attached to other particles until they have decayed to more reactive kinds of atoms -- by which time most of the larger particles have already fallen out. The result is a depletion of the decay products of these gases in the local fallout and a corresponding enrichment of the decay products in the small particles which tend to remain aloft longer and be deposited at greater distances.[10] This process, known as fractionation, is an important one since it has been observed to occur for several important radioactive products in the fallout from land surface bursts -- including strontium-90, which is a decay product of the noble gas krypton, and cesium-137, which also has gaseous precursors and is one of the principal gamma-ray emitters at very late times.[1,11]

land burst close in fallout:

millimeters to perhaps 1/2 millimeter in diameter,[13] with the largest particles carrying the most radioactivity,[14] and would be clearly visible against most backgrounds[15,16] (Visual Aid 1, demonstrating ~ 1000 r/hr fallout). The overall impression might be much like being in a mild desert sandstorm. While this was happening the concentration of the material passing through the air near him and the gamma radiation dose he was receiving would be building up steeply to a level of 1000 r/hr or more (Figure 5a); also the average energy of the gamma rays, reflected in penetrating power, would probably be higher at these early times (~ 20 min).[17] After about the same length of time it took for the particles to arrive in the first place,[18] the rain of large particles would diminish; and radioactive decay would begin to predominate, as shown in the figure.[1] It is to be noted that at first, because of the presence of induced products, the dose rate would probably not decrease as fast as the average usually estimated[8] for mixed fission products ($\propto t^{-1.2}$), while later it would drop much more rapidly due to an overall decrease in the ionizing power of the radiation[3,16,19,20] (Figure 6; note logarithmic scale). This decay might be interrupted by the late arrival of groups of particles from higher altitudes if the high-level winds reverse themselves. These large particles would not present a serious inhalation hazard, could be easily brushed off clothes and skin, and once on the ground would tend to resist movement by surface winds.

Note: Triffet's 1961 report WT-1317 shows that these curves are scaled up from test ZUNI, a clean bomb

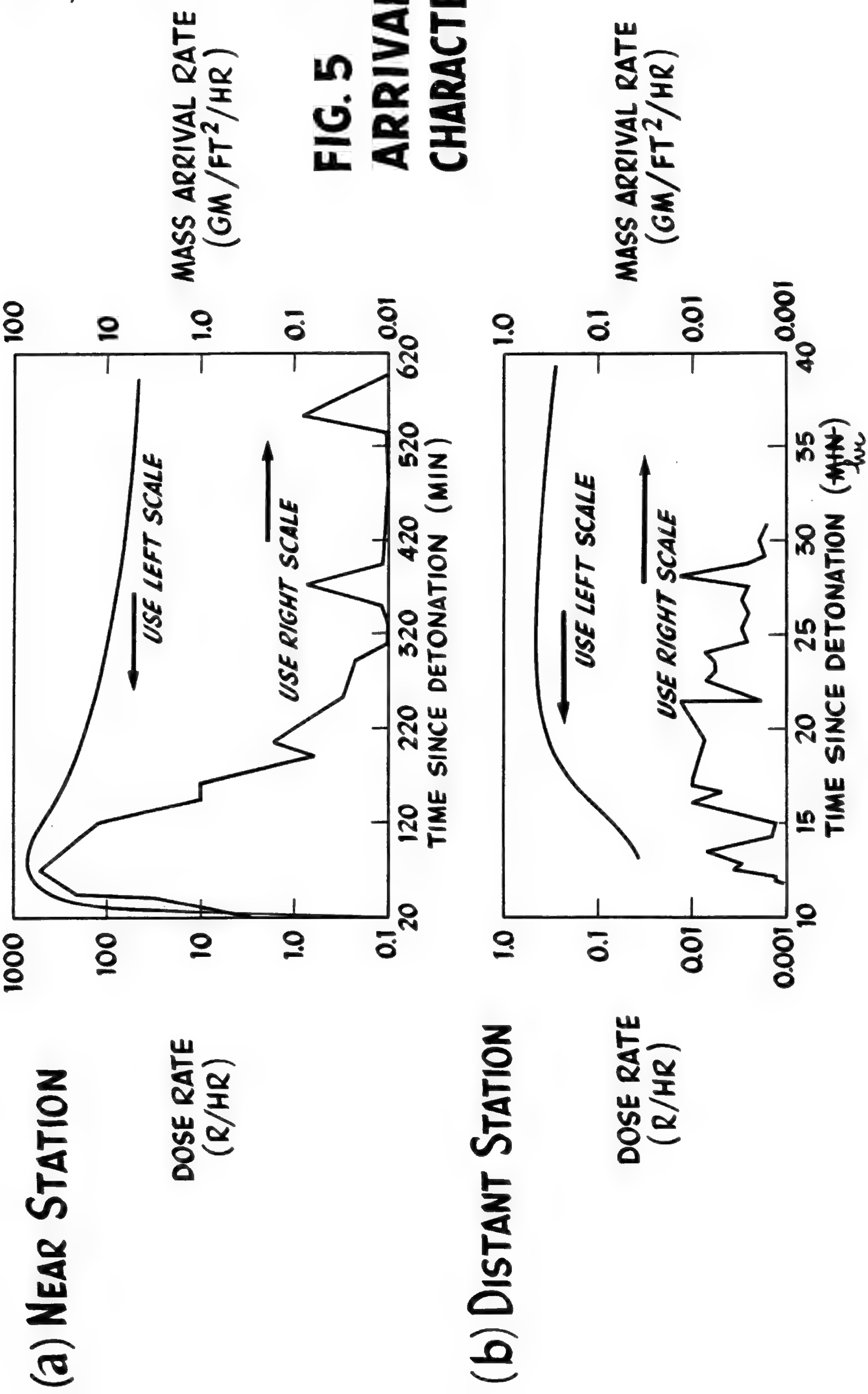


FIG. 5 ARRIVAL CHARACTERISTICS

References 22 and 4:
Tests (a) TEWA
and (b) SUGAR

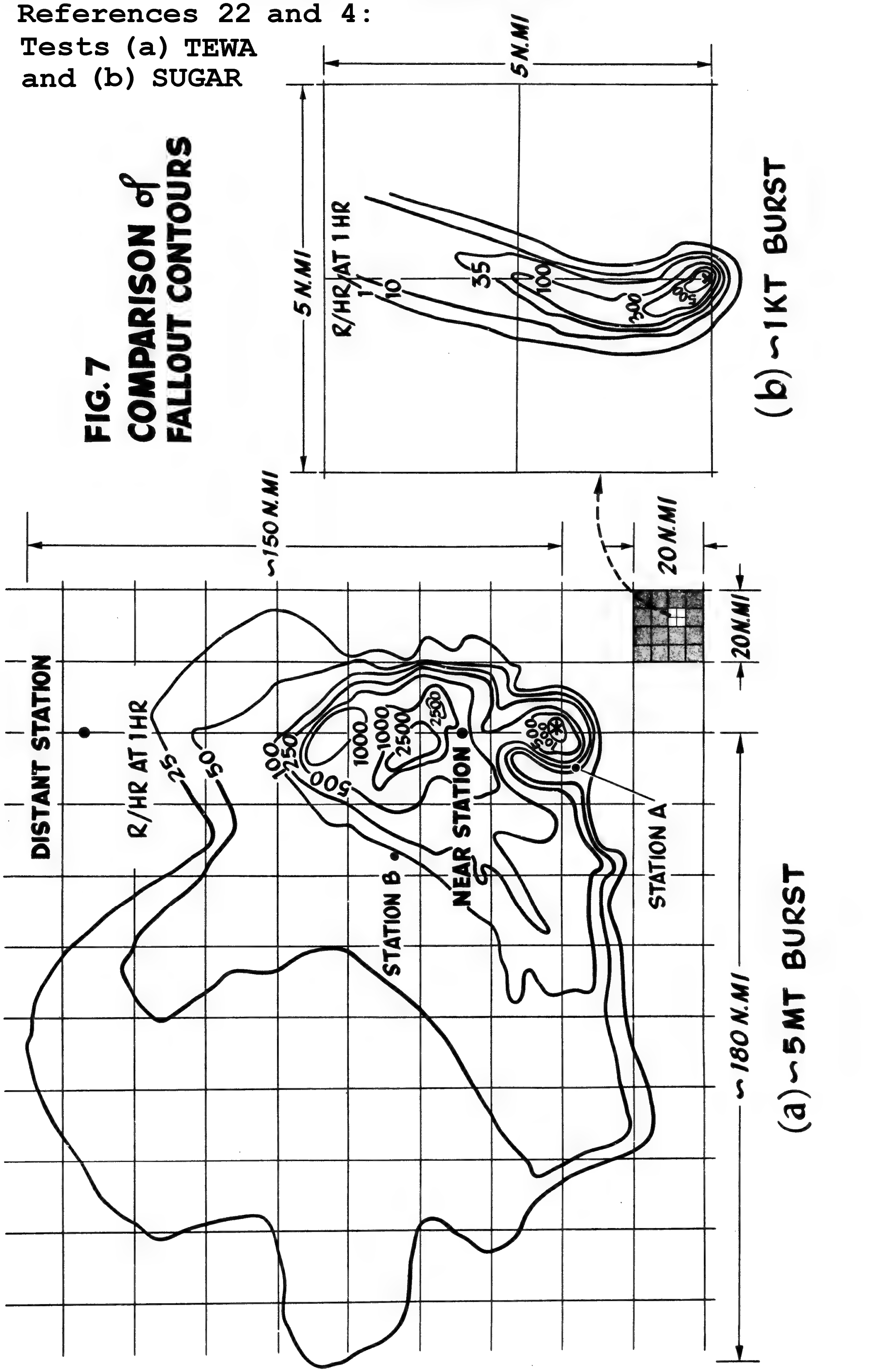
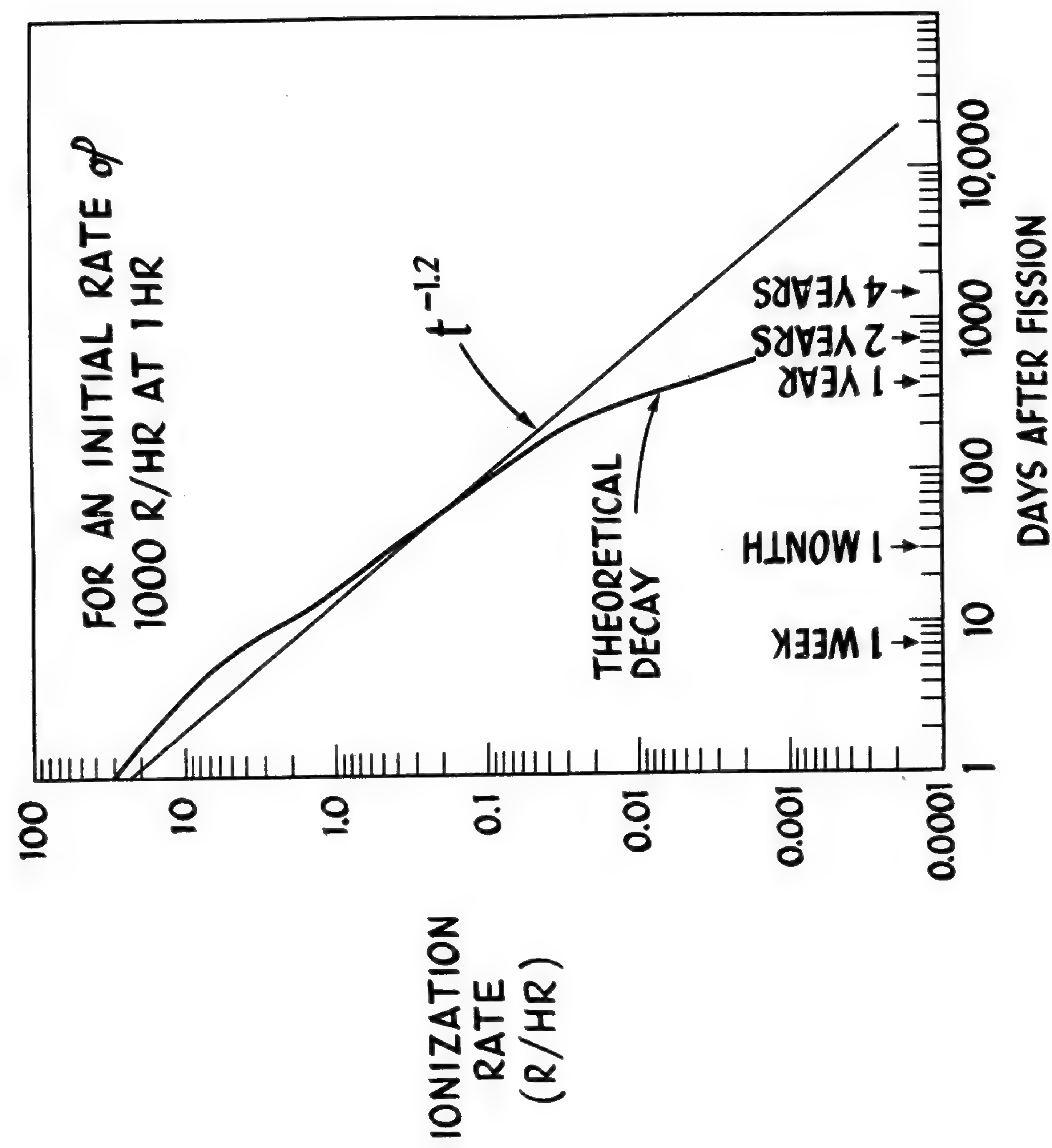


FIG. 7
COMPARISON of
FALLOUT CONTOURS

FIG. 6
RADIOACTIVE DECAY RATE



Background for Triffet's tables and graphs:

~~possible to avoid vagueness.~~ While they are based on the best experimental data and theoretical results available at the present time, they are nevertheless interpretive rather than literal -- sometimes utilizing what appears to be good data from a single test and other times combining the results of many tests and analyses. The data and results are also far from complete and, as explained earlier, may not even be strictly applicable in some cases. It is urged that all possible caution be exercised in the use of the stated values, and that the references indicated in the preceding discussion be studied before each important application. In general only those references which are essential, and which have appeared since the first congressional hearings on this subject, have been listed.

Triffet's tables and graphs follow

TABLE 1

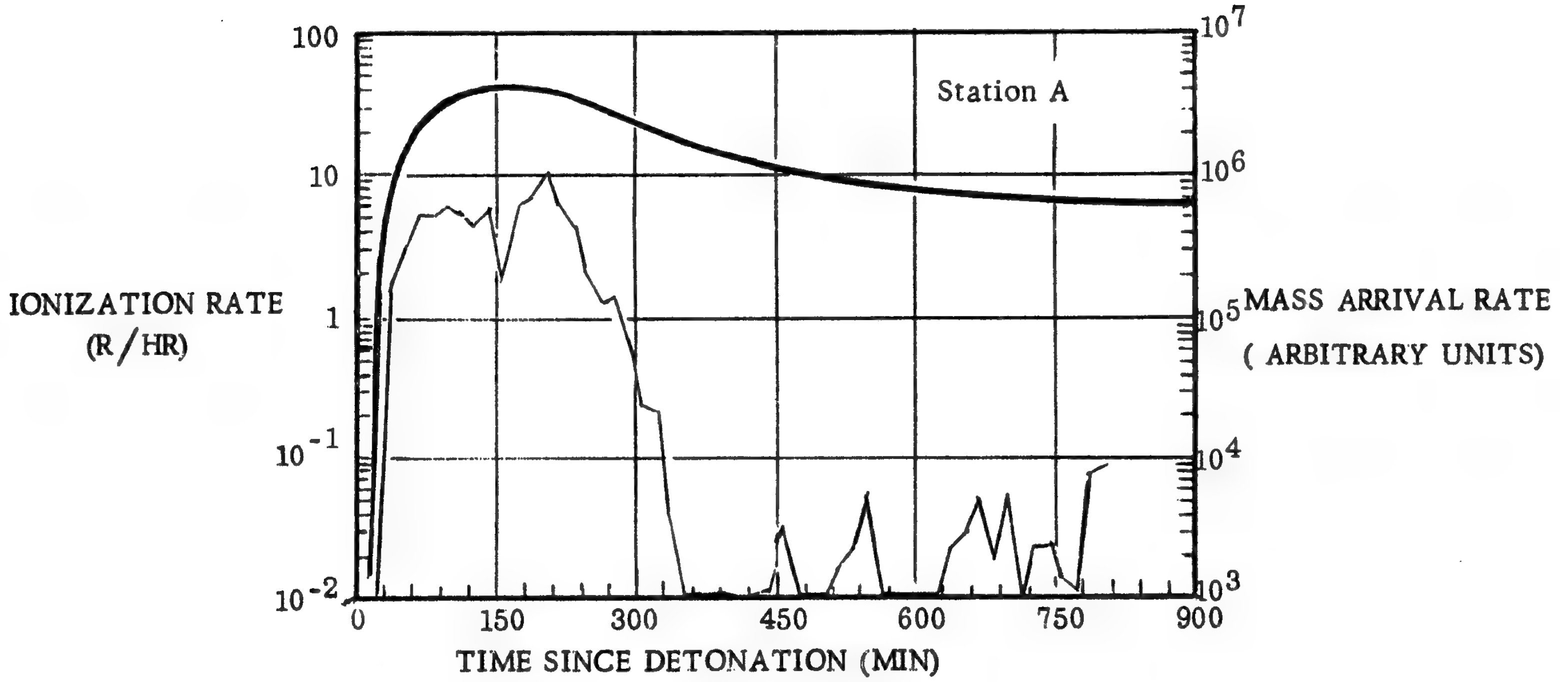
ARRIVAL CHARACTERISTICS OF LAND SURFACE BURST FALLOUT

REDWING – TEWA, 5.01 Mt (DECLASSIFIED DATA ADDED FROM TRIFFET WT-1317.)

Characteristics	Station A	Station B
WT-1317, p. 61 →	Station A ← YFNB29	Station B ← LST611
USNRDL-466, pp. 20-21 →	($\sim$8 mi downwind) 7.84 Stat. miles WSW.	($\sim$60 mi downwind) 59.3 Stat. miles N.W.
Time of Arrival	0.23 $\sim$0.25 hr since detonation	7 $\sim$ 7 hr since detonation
Time of Peak	2.7 $\sim$1.5 "	14 $\sim$13.5 "
Time of Cessation	16 $\sim$6 "	16 $\sim$16 "
Rate of Arrival	See Fig. 8a	See Fig. 8b
Peak Dose Rate	40 $\sim$40 r/hr	0.256 $\sim$ 0.25 r/hr
Total Mass Deposited	4.533 $\sim$ 4.5 gm/ft^2	0.0629 $\sim$ 0.06 gm/ft^2
Total Radioactivity Deposited	$\sim$ 2.7 x 10^{15} fiss/ft^2	$\sim$ 9.5 x 10^{13} fiss/ft^2

TRIFFET HAS NOT CONVERTED THESE FROM 87% TO 50% FISSION BOMB YIELD!

TEWA shot barge YFNB29 (Triffet, WT-1317)



TEWA shot ship LST611 (Triffet, WT-1317)

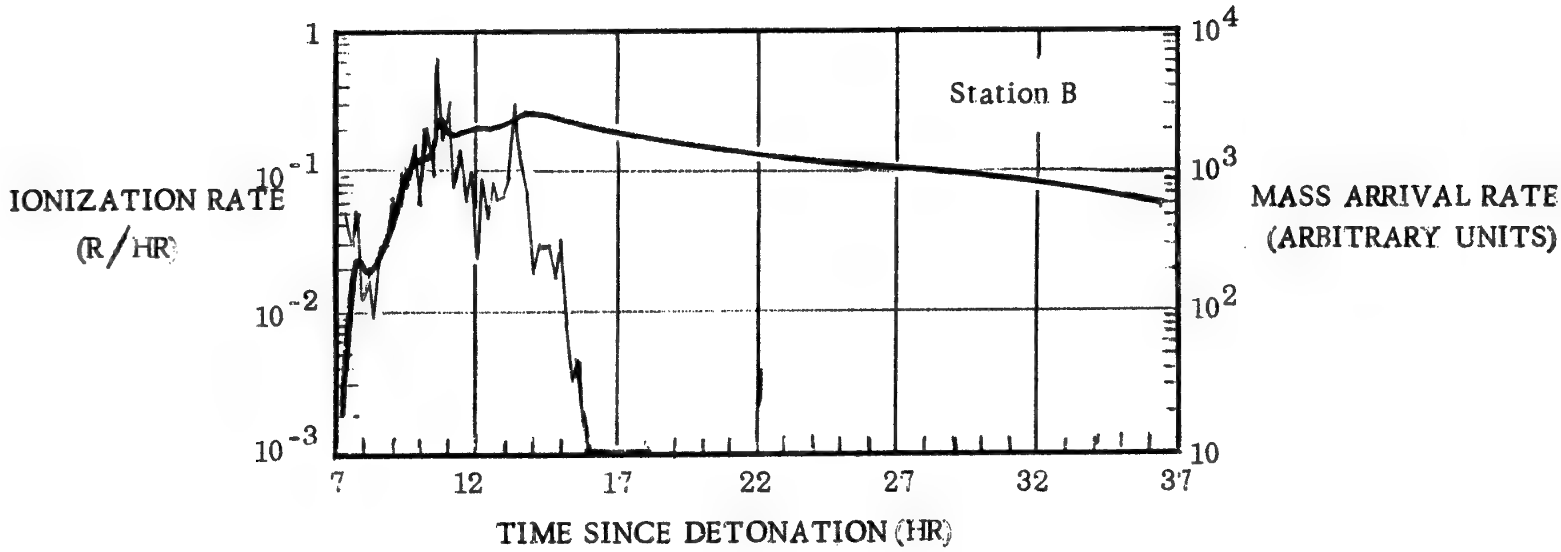


FIGURE 8 LAND SURFACE BURST FALLOUT RATE OF ARRIVAL

TABLE 2

PHYSICAL PROPERTIES OF LAND SURFACE BURST FALLOUT

<table>
<tr><th>Properties of Particles*</th><th>Station A
($\sim$ 8 mi downwind)</th><th>Station B
($\sim$60 mi downwind)</th></tr>
<tr><td>General Description</td><td colspan="2">Melted, glassy solid containing air bubbles and mineral grains.</td></tr>
<tr><td>Range of Diameters</td><td>$\sim$ 0.075 to 1.5 millimeter</td><td>$\sim$ 0.050 to 0.30 millimeter</td></tr>
<tr><td>Predominant Size</td><td>$\sim$ 0.35 millimeter in diameter</td><td>$\sim$ 0.10 millimeter in diameter</td></tr>
<tr><td>Color</td><td colspan="2">Transparent to opaque, pale green or yellow to brown or black.</td></tr>
<tr><td>Shape</td><td colspan="2">Spherical to irregular.</td></tr>
<tr><td>Specific Gravity</td><td colspan="2">$\sim$ 1.4 - 2.6 gm/cm^3</td></tr>
<tr><td>Distribution of Radioactivity</td><td colspan="2">Irregularly throughout.</td></tr>
<tr><td>Relation of Radioactivity to Size</td><td colspan="2">$A \propto D_{max}^{\sim 3}$, but with the range of A increasing with D_{max}.</td></tr>
</table>

* Based on properties of particles from kiloton bursts on silicate sand; all other information derived from megaton bursts on coral sand.

TABLE 3

CHEMICAL AND RADIOCHEMICAL PROPERTIES OF LAND SURFACE BURST FALLOUT

Properties	Station A (∼8 mi downwind)	Station B (∼60 mi downwind)
Principal Components	Silicates, iron oxide.	
Relative Solubility	Less than 3% of the radioactivity soluble by leaching for several days with water.	
		Nevada fallout
Principal Fission		
Gamma Emitters		
1-2 hr	Cs, Te, I, Nb	
13-14 hr	I, Y, Nb, Sr	
1 yr	Nb, Zr, Pr, Ba	
Beta Emitter	Sr^{90}	
Principal Induced		
Gamma Emitters		
1-2 hr	U^{239}, Np^{239}, Na^{24}	
13-14 hr	Np^{239}, Na^{24}, U^{237}	
1 yr	Co^{60}, Mn^{54}, Co^{58}	
Beta Emitter	C^{14}	
Relative Fractionation (Mo^{99})		
Important Products	Sr^{90}, Cs^{137}	Sr^{90}, Cs^{137}
% Depletion	∼80 ∼85	50-65 55-65
Initial Partition-% in Local Fallout		
% Total Fissions (Mo^{99})	90-95	
% Important Products	Sr^{90}, Cs^{137} 45-70 10-30	

TABLE 4

RADIATION CHARACTERISTICS OF LAND SURFACE BURST FALLOUT

Characteristics	Station A (∼ 8 mi downwind)	Station B (∼ 60 mi downwind)
Ionization Decay Rate	See Fig. 9	See Fig. 9
Average Energy		
1 hr	--	∼ 1.0 mev
2 hr	--	0.95
1/2 day	--	0.60
1 day	--	0.40
1 week	∼ 0.25 mev	0.35
1 mo	0.45	0.65
2 mo	0.55	0.65
1 yr	--	0.55

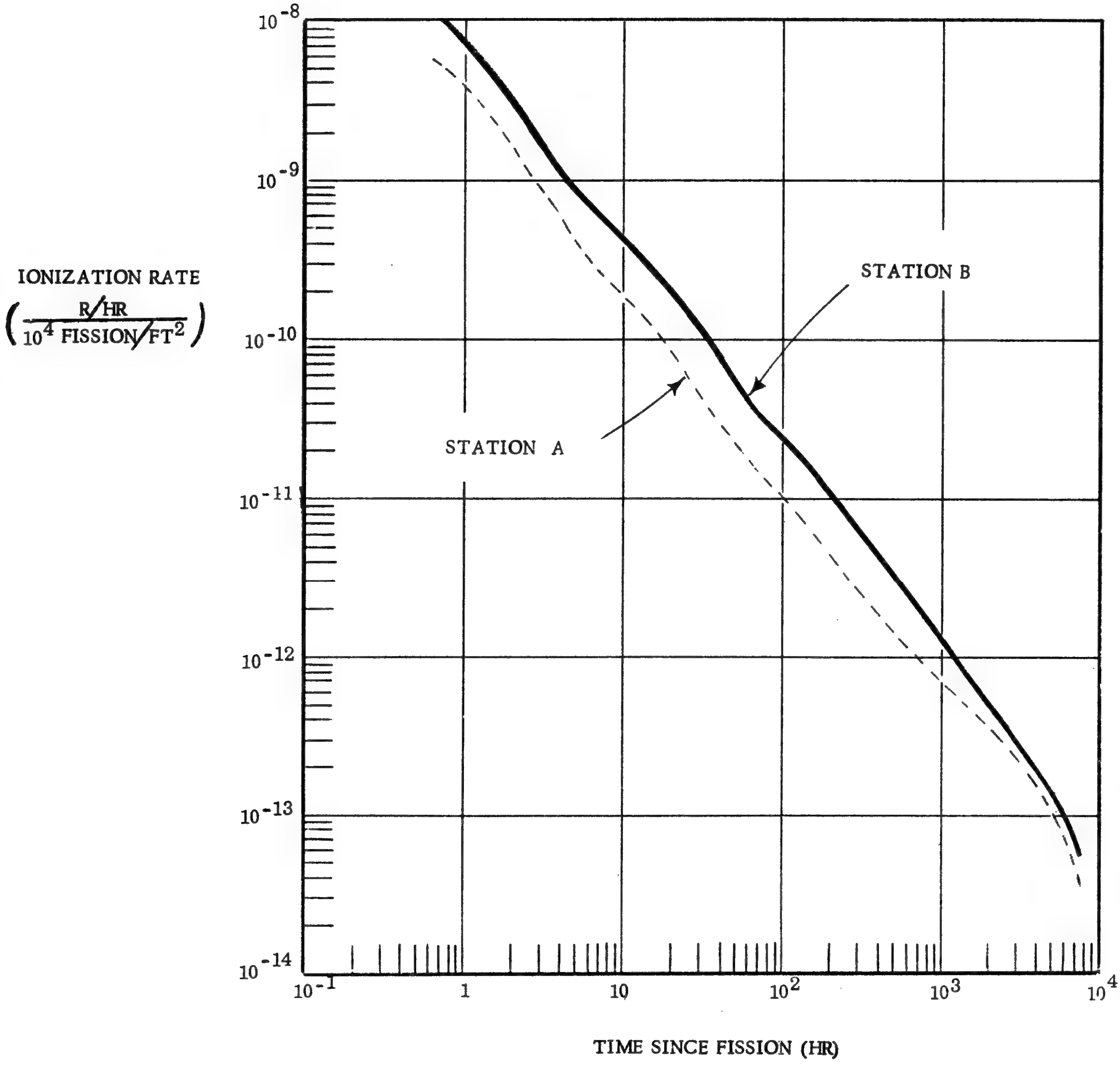


FIGURE 9 LAND SURFACE BURST RADIOACTIVE DECAY RATE

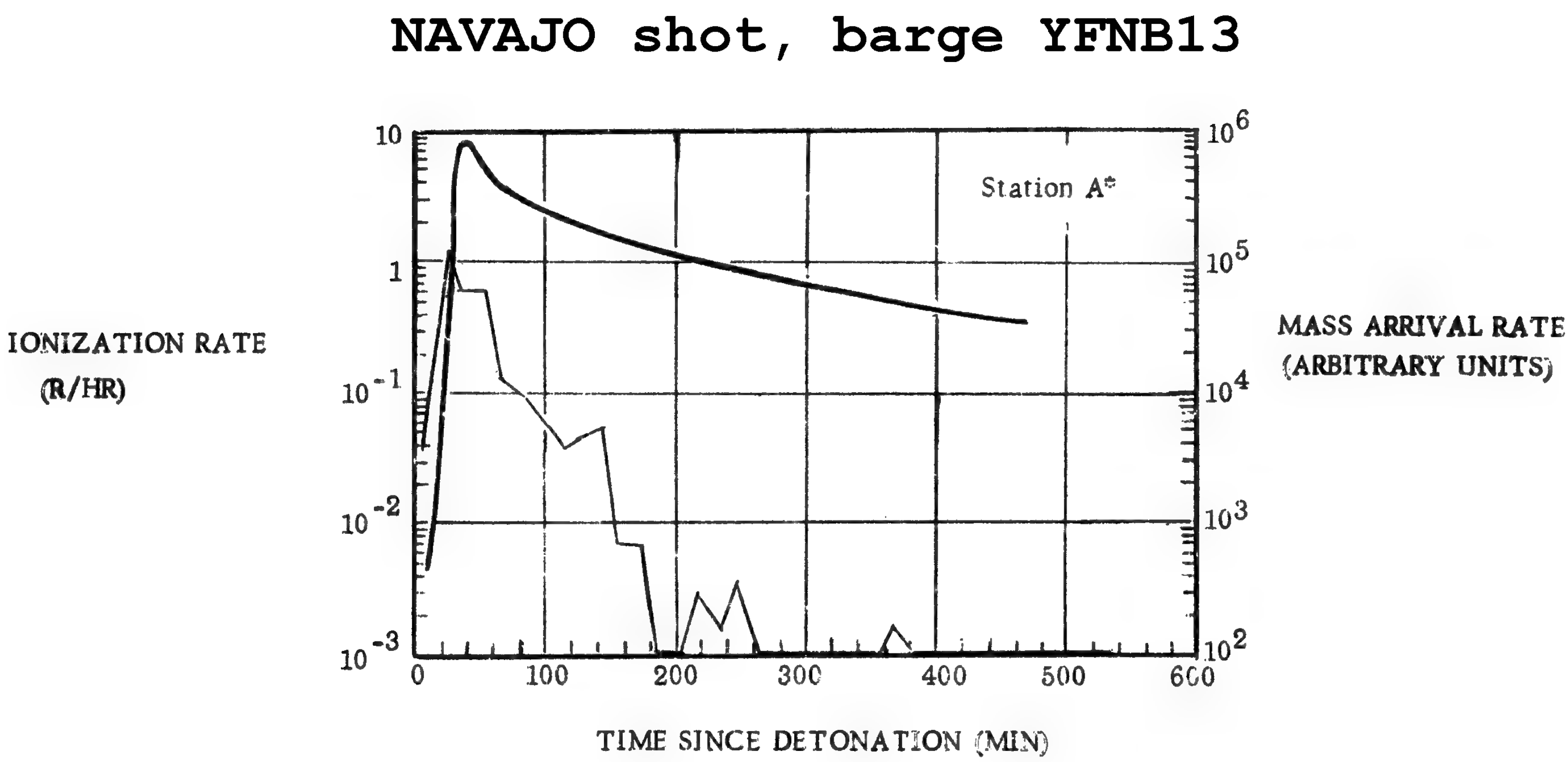
TABLE 5

ARRIVAL CHARACTERISTICS OF WATER SURFACE BURST FALLOUT

TRIFFET & LARIVIERE, WT-1317 (1961) IDENTIFIES THIS AS REDWING–NAVAJO

Characteristics		Station A* YFNB13		Station B* YAG39
Locations from WT-1317 pp. 61–. & USNRDL-466 pp. 20–21.		(~7 mi downwind) 7.54 Stat. miles downwind		(~22 mi downwind) 21.0 Stat. miles downwind
Time of Arrival		~0.20 hr since detonation		~2.3 hr since detonation
Time of Peak	0.63	~0.65 "	double peak! diffusion of small particles for many hours after burst!	~6 "
Time of Cessation	6	~3 "		~16 "
Rate of Arrival		See Fig. 10a		See Fig. 10b
Peak Dose Rate		~8.5 r/hr	1.49	~1.5 r/hr
Total Mass Deposited	5.182	~5.1 gm/ft^2	1.419	~1.4 gm/ft^2
Total Radioactivity Deposited		~5.7 x 10^{14} $fiss/ft^2$		~1.5 x 10^{14} $fiss/ft^2$

* Contours not shown; similar to Fig. 7a.



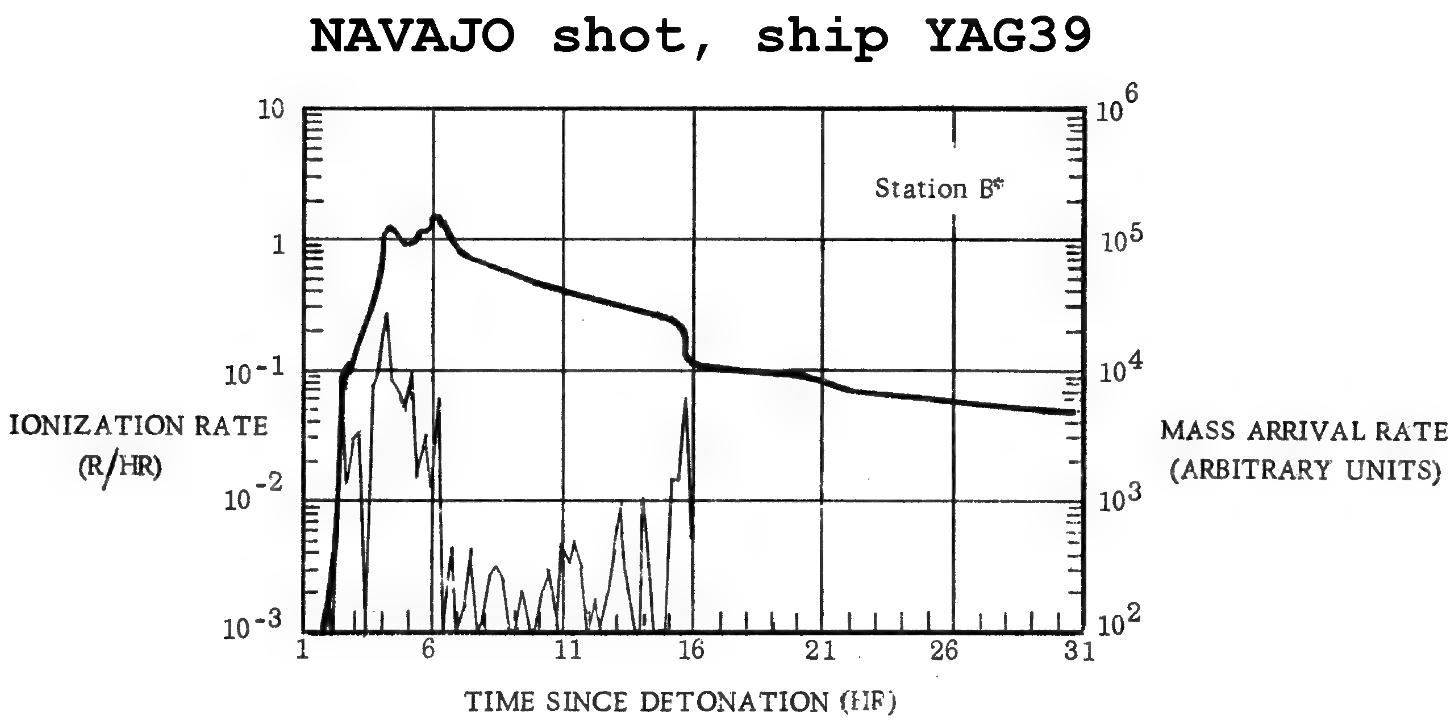


FIGURE 10 WATER SURFACE BURST FALLOUT RATE OF ARRIVAL

TABLE 6

PHYSICAL PROPERTIES OF WATER SURFACE BURST FALLOUT

Properties of Particles	Station A* ($\sim$7 mi downwind)	Station B* ($\sim$22 mi downwind)
General Description	Salt slurry droplet containing insoluble solids.	
Range of Diameters	$\sim$ 0.08 to 0.30 millimeter	
Predominant Size	$\sim$ 0.275 millimeter in diameter	$\sim$ 0.225 millimeter in diameter
Size Range of Insoluble Solids	0.03 millimeter in diameter to sub-microscopic.	
Color	Droplets translucent white, solids amber.	
Shape	Droplets spherical, solids agglomerated spherical.	
Specific Gravity	$\sim$ 1.3 gm/cm^3	
Distribution of Radioactivity	Approximately equal partition between soluble and insoluble components.	
Relation of Radioactivity to Size	$A \propto$ NaCl Wt.	

*Contours not shown; similar to Fig. 7a.

TABLE 7

CHEMICAL AND RADIOCHEMICAL PROPERTIES OF WATER SURFACE BURST FALLOUT

Properties	Station A* (~7 mi downwind)	Station B* (~22 mi downwind)
Principal Components	Sodium chloride, water.	
Relative Solubility	About 50% of radioactivity soluble in water.	
Solid/Liquid Wt. Ratio	~1	
Principal Fission		
Gamma Emitters		
1/2-1 hr	Cs, Nb, Te	
6-7 hr	I, Y, Kr, Sr, Nb	
1 yr	Nb, Zr, Pr, Ba	
Beta Emitter	Sr^{90}	
Principal Induced		
Gamma Emitters		
1/2-1 hr	U^{239}, Np^{239}, Na^{24}, Cl^{38}	
6-7 hr	Np^{239}, Na^{24}, U^{237}	
1 yr	Co^{60}, Mn^{54}, Co^{58}	
Beta Emitter	C^{14}	
Relative Fractionation (Mo^{99})		
Important Products	Sr^{90}, Cs^{137}	
% Depletion	10-30 35-50	
Initial Partition-% in Local Fallout		
% Total Fissions (Mo^{99})	65-75	
% Important Products	Sr^{90}, Cs^{137} 50-60 25-55	

* Contours not shown; similar to Fig. 7a.

TABLE 8

RADIATION CHARACTERISTICS OF WATER SURFACE BURST FALLOUT

Characteristics	Station A* ($\sim$7 mi downwind)	Station B* ($\sim$22 mi downwind)
γ Ionization Decay Rate	See Fig. 11	
Average γ Energy		
1 hr	$\sim$ 1.0 mev	
2 hr	0.95	
1/2 day	0.60	
1 day	0.40	
1 week	0.35	
1 mo	0.65	
2 mo	0.65	
1 yr	0.55	

* Contours not shown; similar to Fig. 7a.

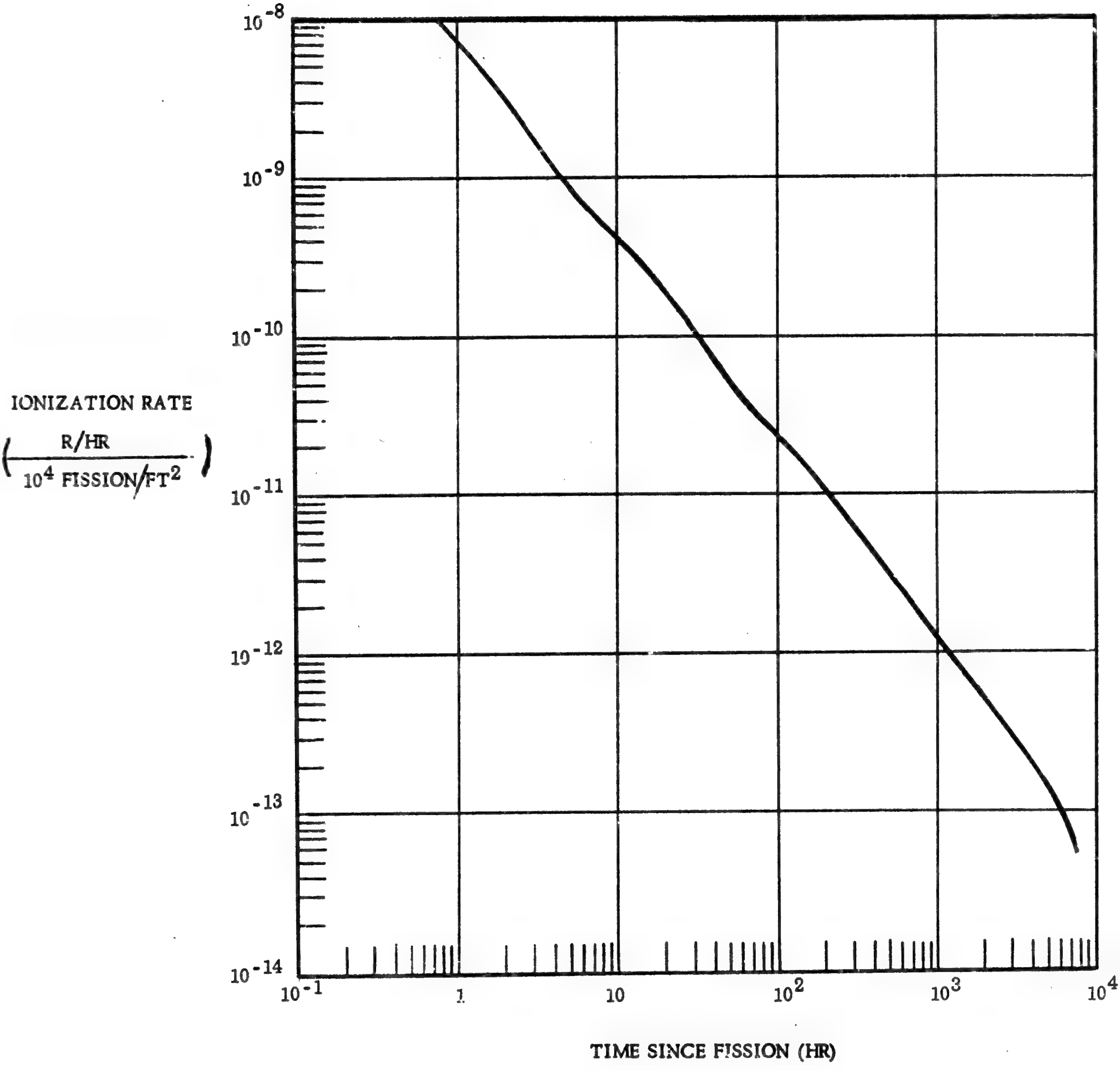


FIGURE 11 WATER SURFACE BURST RADIOACTIVE DECAY RATE

References

1. Triffet, T. and LaRiviere, P.D.; Characterization of Fallout, Volume I; Operation REDWING, Project 2.63, Final Report, August 1958; SECRET-RESTRICTED DATA.

2. Tompkins, E.R. and Werner, L.B.; Chemical, Physical, and Radiological Characteristics of the Contaminant, Project 2.6a, Operation CASTLE, WT-917, September 1955; SECRET-RESTRICTED DATA.

3. Strope, W.E.; Evaluation of Countermeasure System Components and Operational Procedures, Operation PLUMBBOB Final Report, Project 32.3, (in publication), UNCLASSIFIED.

4. Laurino, R.K. and Poppoff, I.G.; Contamination Patterns at Opera-JANGLE; USNRDL-399, April 1953, UNCLASSIFIED.

5. Evans, E.C. III and Shirasawa, T.H.; Characteristics of the Radioactive Cloud From Underwater Bursts, Operation HARDTACK Proj. 2.3, ITR-1621, January 1959, CONFIDENTIAL.

6. The Nature of Radioactive Fallout and its Effects on Man; United States Government Printing Offite, 1957; Statement of Dr. Alvin C. Graves, pp. 53-88, UNCLASSIFIED.

7. Knapp, H.A.; A Review of Information on the Gamma Energy Radiation Rate from Fission Products, and its Significance for Studies of Radioactive Fallout; Office of Operations Analysis and Forecasting, U.S. Atomic Energy Commission, April 1959, UNCLASSIFIED.

8. The Effects of Nuclear Weapons; U.S. Atomic Energy Commission, Washington, D.C., June 1957, UNCLASSIFIED.

9. Adams, C.E., Farlow, N.H. and Schell, W.R.; The Compositions, Structures, and Origins of Radioactive Fallout Particles; USNRDL-TR-209, February 1958, UNCLASSIFIED.

10. Stevenson, P.C.; Measurement of Time of Condensation of Bomb Debris by a Radiochemical Technique; University of California Radiation Laboratory, Livermore, Calif., UCRL-5079, January 1958, UNCLASSIFIED.

11. Whitcher, S.L. and Soule, R.R.; Aircraft and Rocket Fallout Sampling,

Proj. 2.8, Operation HARDTACK, WT-1625 (in preparation); SECRET-RESTRICTED DATA. published in J. Meteorology v17 (1960), pp. 390-399

12. Farlow, N.H.; Atmospheric Reactions of Slurry Droplet Fallout; USNRDL-TR- (in preparation), UNCLASSIFIED.

13. Hendricks, J.W.; Fallout Particle Size Measurements From Operation REDWING, Vol. I: An Explanation and Survey of the Data; USNRDL-TR-264, May 1959. CONFIDENTIAL (Formerly RD).

14. Chan, H.K.; Activity-Size Relationship of Fallout Particles From Two Shots, Operation REDWING; USNRDL-TR-314, February 1959, UNCLASSIFIED.

15. Schuert, E.A.; Fallout Studies and Assessment of Radiological Phenomena, Operation PLUMBBOB, Proj. 32.4, (in preparation), CONFIDENTIAL. weapon test report WT-1465 (1959)

16. The Nature of Radioactive Fallout and Its Effects on Man; United States Government Printing Office, 1957; Statement of Dr. C. F. Miller, pp. 309-315, UNCLASSIFIED.

17. Mather, R. L., Johnson, R. F., Tomnovec, F. M., Cook, C.S., Gamma Radiation Field Above Contaminated Ground; WT-1225, Operation TEAPOT, Proj. 2.3b, June 1959, CONFIDENTIAL

18. LaRiviere, P.D.; The Relationship of Time of Peak Activity From Fallout to Time of Arrival; USNRDL-TR-137, February 1957, UNCLASSIFIED.

19. Miller, C.F.; Gamma Decay of Fission Products from the Slow-Neutron Fission of U^{235}; USNRDL-TR-187, July 1957, UNCLASSIFIED.

20. Miller, C.F. and Loeb, P.; Ionization Rate and Photon Pulse Decay of Fission Products from the Slow-Neutron Fission of U^{235}; USNRDL-TR-247, August 1958, UNCLASSIFIED.

21. Larson, K.H., Neel, J.W. and Associates; Summary Statement of Findings Related to the Testing Program at Nevada Test Site; UCLA-438, The University of California Los Angeles Campus, School of Medicine, April 1959, UNCLASSIFIED.

22. Van Lint, V. A. J., Killian, L. E., Chiment, J. A. and Campbell, D. C.; Fallout Studies During Operation REDWING: Program 2, Operation REDWING; ITR-1354, October 1956, SECRET-RESTRICTED DATA.

← REDWING-TEWA, 5.01MT

real event. Obviously it is a Pacific test, because it is in the megaton range. The much smaller set of contours on the right represents a Nevada test. (JANGLE-SUGAR, 1951, 1.2 KT)

I have also attempted to show the near station and the distant station which I have been discussing in terms of fallout properties. These cannot be interpreted too literally but they are at least indicative.

Representative HOLIFIELD. Is the point you are making here that the actual contour, in the place of being elongated and more like the shape of a banana, let us say, is wider and more an irregular round type of shape as you have on the left?

Dr. TRIFFET. There are in fact three points I want to make and the first one is that. The contours from the large burst are very irregular compared with those from the small burst. This is because the megaton burst produces a cloud which rises into the high level winds, and these may vary in direction. When they vary in direction the kind of a pattern indicated as (a) may result.

Representative HOLIFIELD. Will you trace the center roentgen level there out to the different contours?

Dr. TRIFFET. That leads directly to the second point I want to make. Near ground zero there is a 1,000 r./hr. at 1 hour contour with a 500 r./hr. contour adjacent to it. Next there are contours which, in general, step down to 250, 100, 50, and 25 r./hr.

FICTIONAL, NOT HYPOTHETICAL?

Representative HOLIFIELD. That is upwind.

Dr. TRIFFET. Yes, sir. Notice, however, that downwind, because of the effect of varying winds at higher levels, there is a 2,500 r./hr. region perhaps 40 nautical miles from ground zero. Another 1,000 r./hr. area appears further out still.

Representative HOLIFIELD. According to that, your high areas of intensity may be some distance from point zero.

Dr. TRIFFET. That is correct.

Representative HOLIFIELD. What would this do to the maps we saw this morning? If this type of contour had been used would it not have changed the readings of the maps we had before us this morning?

Dr. TRIFFET. Yes, it would. What these two things I have brought out mean, is that, inside the fallout area from a real megaton burst, it is altogether possible to receive widely different radiation doses at points which are not too far removed, from one another. Consider the near station, for example. Within about 10 miles of there, one could have received 2,500 r./hr. while within about 20 miles of the same spot one could have received less than 25 r./hr.

I do not want to overemphasize this situation though for the following reason. Notice the contours of the 1 kiloton burst. The cloud did not get into the high-level winds in this case; consequently, it is easy to see how the contours could be generalized into a cigar shape.

Representative HOLIFIELD. Isn't it true that it would be in a cigar shape if it did not go into the stratosphere, and if it were below the troposphere?

Dr. TRIFFET. I cannot say definitely. These contours are somewhat irregular, and they would generally be, I think.

Representative HOLIFIELD. We understand that these are idealized to a certain extent. They are not absolutely accurate. It is an attempt to draw the pattern of downwind radioactivity. Any bomb that

was low enough in yield to not puncture the troposphere would be inclined to have more of a regular downwind pattern than one that went above 60,000 feet. Is that not true?

Dr. TRIFFET. Yes. There is another factor that should be brought out, too, and that is that the winds over the Eniwetok Proving Grounds have a tendency to vary more than the winds over the United States—the high-level winds, that is. This means that it might be possible to get a less irregular pattern in the United States—although there is a lot of evidence for removed hot spots and some irregularity in any case.

Representative HOLIFIELD. This irregular pattern does not necessarily mean that your spread of radioactive intensity with a multiple weapon attack such as we have envisaged here, would not have an intense radiation activity which might approximate what was given us this morning?

Dr. TRIFFET. No, it does not mean that, because of the possibility of getting overlapping patterns from different weapons.

Representative HOLIFIELD. You would actually get more overlapping in a pattern of this type which would be expected from the megaton and up weapon than you would from the smaller weapons.

Dr. TRIFFET. I am not sure of that, and would rather not comment on it.

Representative HOSMER. The matter of fact is that a certain wind condition would produce the exact patterns shown on the maps this morning.

Dr. TRIFFET. Yes, very nearly.

Representative HOSMER. But nobody can speculate exactly what the wind conditions are and as a consequence nobody can predict at any time with any degree of accuracy just where the hotspots are going to be, but you can in general attain an order of magnitude idea of what is going to happen over a particular piece of real estate.

Dr. TRIFFET. Yes, that is correct.

Representative HOLIFIELD. If my colleague will change the words "any degree" to "some degree" of accuracy, I will go along with him on that.

Representative HOSMER. I would be happy to accommodate you.

Dr. TRIFFET. Dr. Machta did make the point that the patterns might well be irregular. They have been idealized and this must, of course, be recognized. If there are not further questions, I will go on.

Representative HOSMER. While we are about this, you mentioned fractionation again in discussing this phenomenon here. By your reference to that twice, is there something about it that you could use to actually control fallout to the extent of making more early fallout?

Dr. TRIFFET. This may be possible, and studies are underway along these lines. However, I would rather not discuss them in detail now.

Representative HOLIFIELD. You may proceed.

Dr. TRIFFET. I would like in conclusion to mention one or two things which are often misunderstood about the radioactivity as-

sociated with fallout. These are the following. It should be clear from what I have said that contaminated particles and radioactivity from contaminated particles are two different things. The particles are contaminated in the sense that they are carrying radioactive atoms which are decaying and emitting nuclear radiations. The best analogy, I think, is to compare a particle with a light bulb, and the radiations with the light. The bulb is a substantial physical object, as is a fallout particle. The radiation, on the other hand, is a concentration of energy, like the light. As you move farther away from a lighted bulb, you get less light. This is true of the nuclear radiations from fallout particles, too. Some are very short range radiations, called alpha and beta particles. Gamma rays are not like this, however; they are long-range radiations which penetrate large distances.

Perhaps this will make it clear that internal and external radiation hazards are also two different things. If one is exposed to a contaminated particle which is a long distance away, then only an external radiation hazard from the gamma rays exists. On the other hand, if one has such a particle on his skin, there is a contact hazard from the short-range beta radiation. Even worse, if the particle is swallowed or inhaled an internal hazard is created from all of the radiations the particle is emitting. There are some radioactive products which do not emit gamma rays at all, and therefore pose practically no external radiation hazard. It makes absolutely no sense to compute an external radiation dose for these nuclides; but they may represent a serious internal hazard, nevertheless. Strontium 90, and carbon 14 are two of the principal culprits in this case.

Representative HOLIFIELD. This is because these nuclides, as you say, do not emit long-range energy particles where if they are taken internally and become a part of the bone or muscle structure, then their radiation is for a limited distance in their environment within a person.

Dr. TRIFFET. That is correct. Radiations always damage the body in the same way—or damaging the individual cells through ionization. It is mostly a question of whether the radiation can get to the cells or not. For the gamma rays the source may be a long way off; for beta particles it has to be close.

I think this concludes my remarks, but I will be glad to answer any questions.

Representative HOLIFIELD. Thank you very much. Are there any questions? If not, then we thank you very much for your presentation. I am sure the scientific material you have given us will be very valuable.

Before Dr. Machta begins, I have a paper by Dr. Knapp, of the AEC, for insertion in the record at this point.

"where n (λ, t) is the number of nuclei of decay constant λ existing at time t after a fission. Evaluation of this expression gives, for times greater than one day, the result

$$\text{Mev/sec/fission} = 3.75t^{-1.2} + 96t^{-1.4}$$

where t is measured in seconds. For shorter times a curve is given. This is the total energy emitted, including that carried by neutrinos. Agreement with experimental results is fairly good. Handy rules of thumb giving correct values within a factor of two for times between 10 seconds and 100 days are

$$\beta + \gamma \ ; \ \text{Mev/sec/fission} = 2.66t^{-1.2}$$

$$\gamma \ ; \ \text{Mev/sec/fission} = 1.26t^{-1.2}$$

The total disintegration energy per fission turns out to be 22 ± 3 Mev."

The expression

$$\text{Mev/sec/fission} = 1.26t^{-1.2} \ (t \text{ in seconds})$$

is equivalent to

$$\text{Mev/sec}/10^4 \text{ fissions} = .68t^{-1.2} \ (t \text{ in hours}),$$

so that the γ energy radiation rates predicted by this formula are uniformly 17% greater than those obtained from "The Effects of Nuclear Weapons."

In a summary of the wartime experimental results on the rate of gamma energy radiation from fission products given, in their 1948 Physical Review paper, Way and Wigner list three experimental results which apply to time intervals of interest in fallout research. As given in Physical Review Vol. 73 page 1329, these results are

	Function of Time t after Fission (t in seconds)	When Valid	References
γ energy in Mev/fission/sec =	$.90t^{-1.20}$	10 sec - 1 day	S. Katcoff, B. Finkle, N. Elliot, J. Knight, N. Sugarman Metallurgical Laboratory CC - 1128, Dec. 11, 1943
	$4.2t^{-1.28}$	20 m - 3 days	L. Borst, Metallurgical Laboratory CL-697 VIII, C4
	$49.0t^{-1.41}$	50 - 100 days	

FIRST $t^{-1.2}$ PUBLICATION.

Representative HOLIFIELD. The next witness is Dr. G. S. Hurst from the Oak Ridge National Laboratory. Dr. Hurst, will you please come forward at this time?

STATEMENT OF G. S. HURST,[1] HEALTH PHYSICS DIVISION, OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TENN.

Dr. HURST. Mr. Chairman, I have no visual aids. We had planned to show slides, but these facilities are not available, so if the committee and members would look at the document which we brought, it contains all the illustrations.

This presentation is entitled, "Application of Radiation Dosimetry Studies to the Evaluation of Environmental and Biological Consequences of Nuclear War."

This paper is in two parts. I will read part A. Part B, by J. A. Auxier, will be turned in for the record.

Part A is entitled "Dosimetry of Direct Radiation from Nuclear Weapons."

Section 1 is the introduction.

The main objective of the dosimetry program, currently in effect at AEC contractor sites in the United States and at the Atomic Bomb Casualty Commission (ABCC) in Japan, is to provide a basis for the correlation of the biological effects of radiation on the Hiroshima and Nagasaki populations with the radiation dose. Two types of results from this study have important application to the problem of the evaluation of biological consequences of nuclear war:

(1) Before a complete evaluation of the consequences of nuclear war can be accomplished, one must know the relationship of biological damage in man to the radiation dose. The group of exposed individuals in Hiroshima and Nagasaki presents a unique opportunity for a study of the medical response of a large number of humans to radiation. A long-term study of medical effects in this group is in progress in Japan at the ABCC, operated by the U.S. National Academy of Sciences, National Research Council. The program is conducted in cooperation with the National Institute of Health of the Ministry of Health and Welfare of the Japanese Government, with participation of interested Japanese scientists.

(2) The program initiated for the determination of the radiation doses for individuals located in Japanese houses in Hiroshima and Nagasaki was designed so that results from it may be applied to any problem concerned with protection against prompt weapons radiation. With this more general objective in mind, weapons effects studies were set up to obtain (*a*) the neutron and gamma dose as a function of distance from various kinds of fission weapons, (*b*) the energy spectrum of neutrons and its dependence on distance, (*c*) the angular distribution of neutron and gamma radiation arriving at points located at various distances from the detonation, and (*d*) the shielding characteristics of various materials for prompt weapons radiation. These data are basic to the consideration of the protection afforded by any type of shielding structure, e.g., homes, offices, industrial buildings, and shelters for the general population, and by fox-

[1] Born: Pineville, Ky., Oct. 13, 1927; B.A., Berea College, 1947; M.S., University of Kentucky, 1948; Ph. D., University of Tennessee, 1959 (Capture of Electrons in Molecular Oxygen); Health Physics Division (Section Chief, Radiation Dosimetry Section), Oak Ridge National Laboratory, 1948 to present.

holes, armored vehicles, and special shelters for the military population.

Section II is basic radiation data.

In this section we give examples of weapons effects results which illustrate the type of data referred to in the introduction. All the examples are quoted for nominal fission devices (10 to 20 kilotons).

A. Gamma dose a function of distance

Figure 1 shows a typical air dose versus distance relationship for gamma rays. The gamma dose d(R) in rads is multiplied by the square of the slant range (R), in yards, from the point of detonation to the point of measurement and is divided by the weapon yield in kilotons (kt.). This quantity is then plotted as a function of the slant range in hundreds of yards. To obtain the gamma dose per kt. at some distance of interest, one reads the quantity $d(R)R^2/kt.$ at the distance of interest and divides by the square of the slant range in yards. For example, the gamma dose at 1,000 yards is approximately 300 rads per kt.

ORNL-LR-DWG 30048
Unclassified

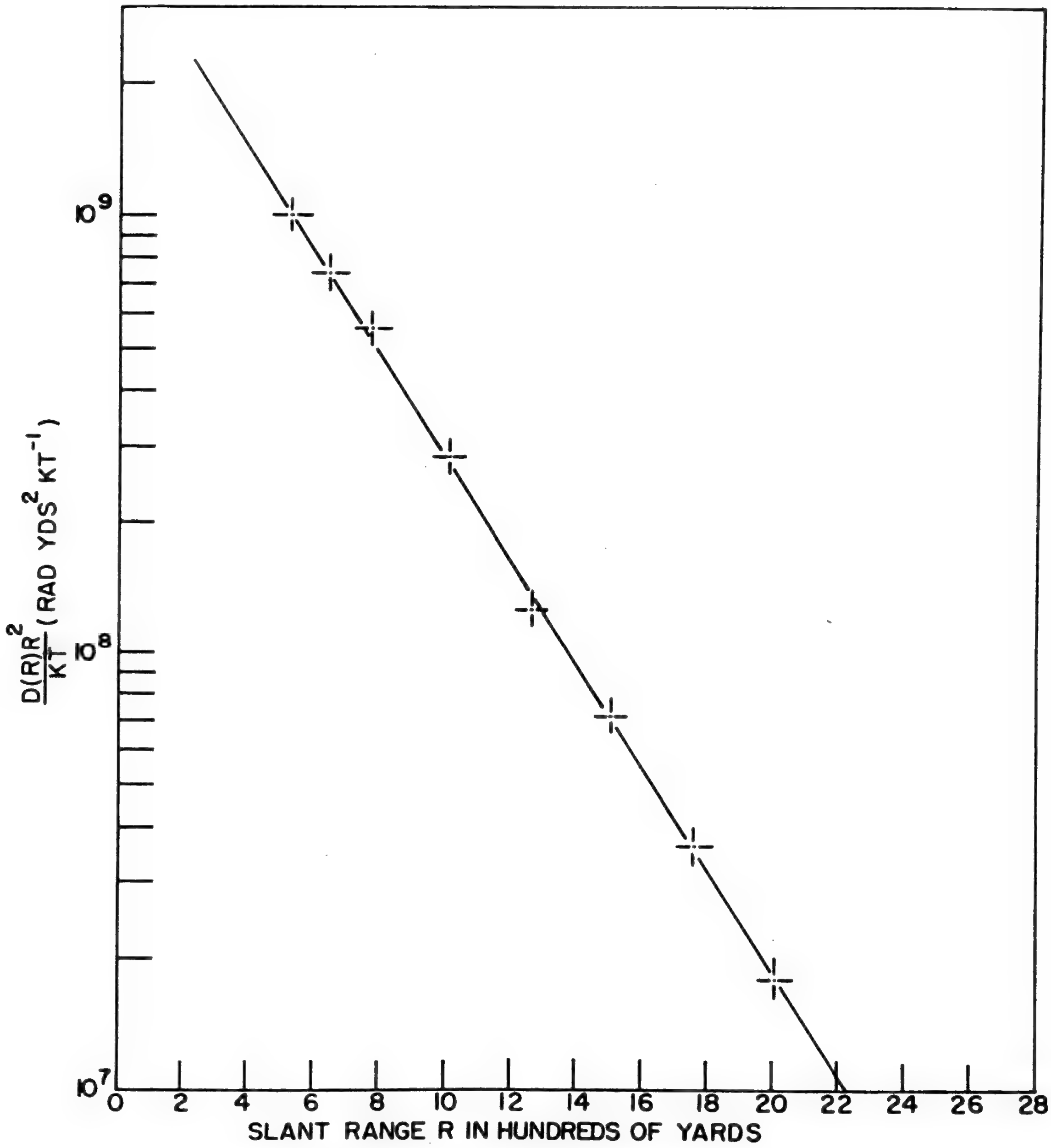


FIG. 1 GAMMA AIR DOSE vs SLANT RANGE FOR A TYPICAL NUCLEAR DETONATION

B. Neutron dose and neutron energy spectrum as a function of distance

Figure 2 shows the same type of presentation of the neutron dose for a typical weapon. For example, it is seen, using the scale to the right, that the neutron dose at 1,000 yards is approximately 350 rads per kt. Figure 2 also shows the energy spectrum of neutrons as a function of distance. The scale to the left represents the neutron flux f(R)(n/cm.^{2}) multiplied by the square of the slant range and divided by the weapon yield in kt. Reading from the top curve down shows f(R) times R^2/kt. for the total number of fast neutrons, slow neutrons, neutrons of energy greater than 0.75 Mev., neutrons of energy greater than 1.5 Mev., and neutrons of energy greater than 2.5 Mev., respectively. The fact that these curves are approximately parallel shows that the neutron energy spectrum is approximately independent of slant range.

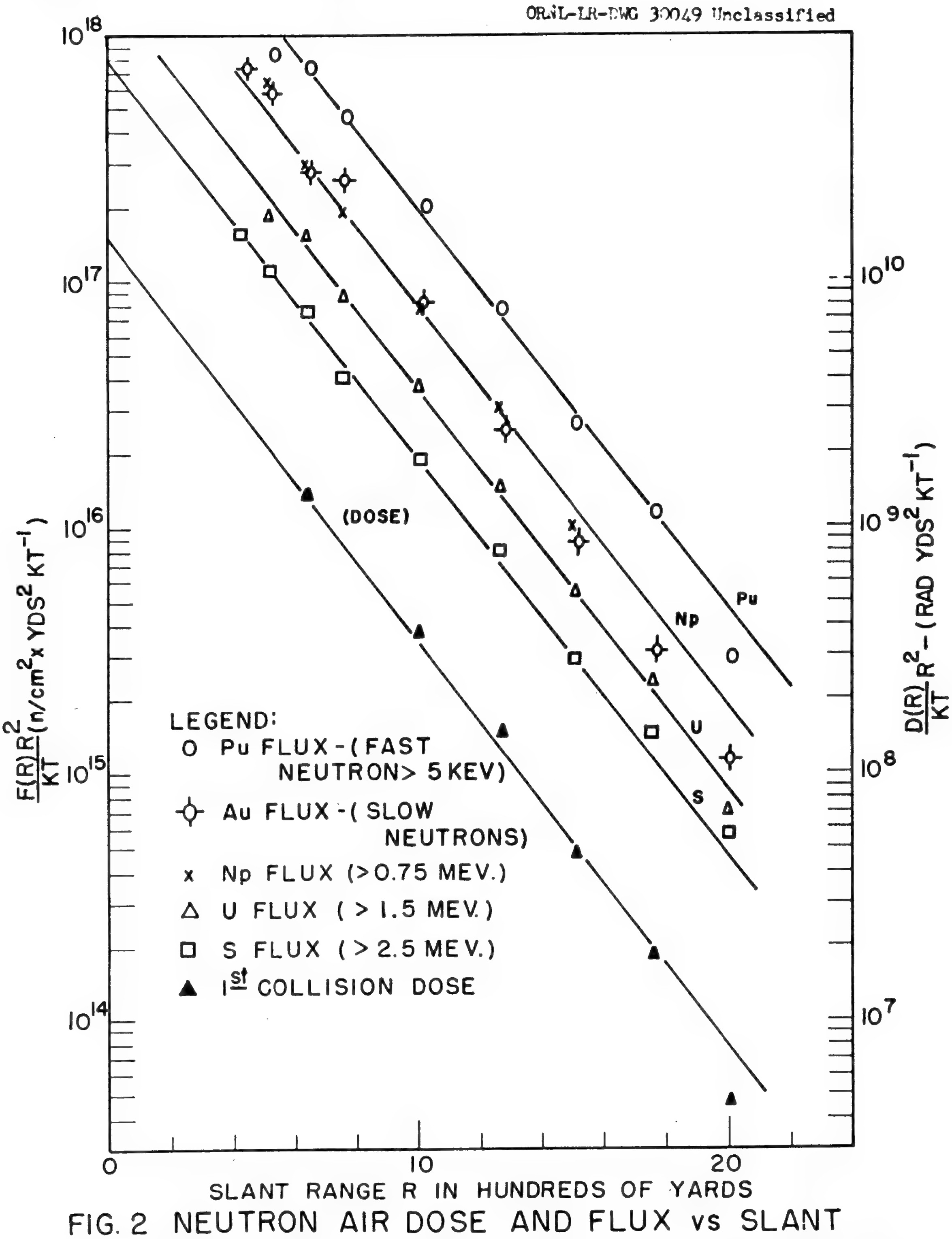


FIG. 2 NEUTRON AIR DOSE AND FLUX vs SLANT RANGE FOR A TYPICAL NUCLEAR DETONATION

E. Mutual shielding in a cluster of light frame houses

In the Hardtack Phase II Operation (Nevada, 1958) seven houses, representative of Japanese design but constructed of substitute American materials, were used in three different experiments. The houses consisted of three sizes: (*a*) a medium-sized single story, (*b*) a large two story, and (*c*) a small single story. These houses were used in various arrangements to determine (*a*) the effect of house size and (*b*) the effect of mutual shielding. Some of the neutron data are quoted as an illustration of the type of results obtained.

The small single-story house attenuated the neutron dose to 0.51 (numbers given are the ratios of the doses inside the houses to the doses with no houses present) when used alone, but when placed behind the medium-sized single story house, i.e., the side farthest from the detonation, the neutron dose was reduced to 0.33, and when placed behind the large two story house the neutron dose was reduced to 0.29. When the large two story house was used alone the neutron dose on the first level was reduced to 0.41, and on the second level the neutron dose was reduced to 0.45. When the medium-sized single story house was placed alongside the large two story house, the dose on the first level was reduced to 0.35 and the dose on the second level was reduced to 0.44. Likewise, when the medium-sized single story house was used alone the neutron dose was reduced to 0.43, and when placed at the side of the large two-story house, the neutron dose was reduced to 0.37.

It is seen from these studies that even if a large house is placed in front of a small house the neutron dose inside the small house is not reduced by a large factor, which is consistent with the angular distribution work reported above.

More details of the information presented in this section can be found in an article by R. H. Ritchie and G. S. Hurst ("Health physics 1," 390, 1959) and in Weapons Tests Reports WT–1504 and WT–1725,

In conclusion, the angular distribution data, together with experimental data on the attenuation of plane slabs, were used to calculate the attenuation by the light frame structures. Theoretical and experimental results were in good agreement; thus it is reasonable to expect that the radiation protection afforded by various other kinds of structures can be obtained from the basic data on angular distributions and plane slab attenuation.

The main uncertainty in the present knowledge of the dose received by individuals being studied in Japan lies in the air dose. The most effective way to normalize the basic information presented above to the Japanese cases would be to detonate reconstructions of the two weapons fired over Japan. Air dose measurements from these devices would then complete the information needed on radiation dose and would provide a basis for the correlation of medical effects in Japan with radiation dose.

That completes the formal presentation, Mr. Chairman.

Representative HOLIFIELD. You have asked that part B be placed in the record at this point?

Dr. HURST. Yes, sir.

Representative HOLIFIELD. Without objection, that will be done at this point.

Calculations based on these data, or normalized to them, permit extrapolation to a large variety of houses. In addition to the evaluation at ORNL, calculational programs of two different types are underway at NBS and at Project Civil. In addition, a theoretical study is underway in England and the workers there are utilizing the data available in the report of this experiment.

III. SHIELDING EXPERIMENTS WITH OAK RIDGE HOMES

To evaluate existing homes complete with normal furnishings and built on uneven and sloping terrain, a corollary experiment is being conducted in Oak Ridge, Tenn., by ORNL in collaboration with the AEC and local homeowners. Although not so basic as the study at the Nevada test site, the measurements in Oak Ridge will permit an extension of calculations based on the earlier fundamental data and will yield experimental information for analyzing the shielding already generally available to the population. In addition, the data will be directly applicable to many homes in the communities which were initially established because of the atomic energy program, and in which the AEC necessarily has a vital interest.

Mr. HOLIFIELD. I would like at this time to introduce a paper by Dr. Charles M. Eisenhauer of the Atomic and Radiation Physics Division of the National Bureau of Standards.

SHIELDING FROM FALLOUT RADIATION

(By Charles M. Eisenhauer [9])

In any realistic appraisal of the casualties that might result from fallout radiation, we must know how radiation dose rate levels are modified inside of buildings. Significant progress has been made during the past year, both in calculations and experiments, in obtaining answers to this question. I would like to indicate the nature of these calculations and experiments and to show some of the results which have been obtained.

I. THEORETICAL STUDIES AT THE NATIONAL BUREAU OF STANDARDS

For many years the National Bureau of Standards has been engaged in a program to study the basic penetration properties of nuclear radiations. About 3 years ago the Bureau undertook a study of the penetration of gama radiation in order to provide data on the penetration of fallout radiation into buildings. This work has been sponsored by the Office of Civil and Defense Mobiliaztion.

The penetration of fallout radiation into buildings is illustrated schematically in figure 1. In calculating the dose rates inside of a structure it has been assumed that fallout particles are uniformly distributed on the roof and on the ground surrounding the structure. It has been further assumed that no fallout particles lie inside of the building. Under these assumptions, all radiation that reaches a person inside of the building must originate from radioactive particles outside and must penetrate through the walls and roof of the building.

---

[9] Born in New York City in 1930, Mr. Eisenhauer graduated from Queens College in 1951, where he majored in mathematics. He also did graduate work in physics at Columbia University. He has worked at Brookhaven National Laboratory in the field of experimental neutron physics and at the Armed Forces special weapons project on problems in gamma ray penetration. Now on the staff of the Atomic and Radiation Physics Division at the National Bureau of Standards, he is coordinating theoretical and experimental research on protection afforded by existing homes and structures against nuclear radiation. He is a member of the Radiation Shielding Subcommittee of the National Academy of Sciences Advisory Committee on Civil Defense.

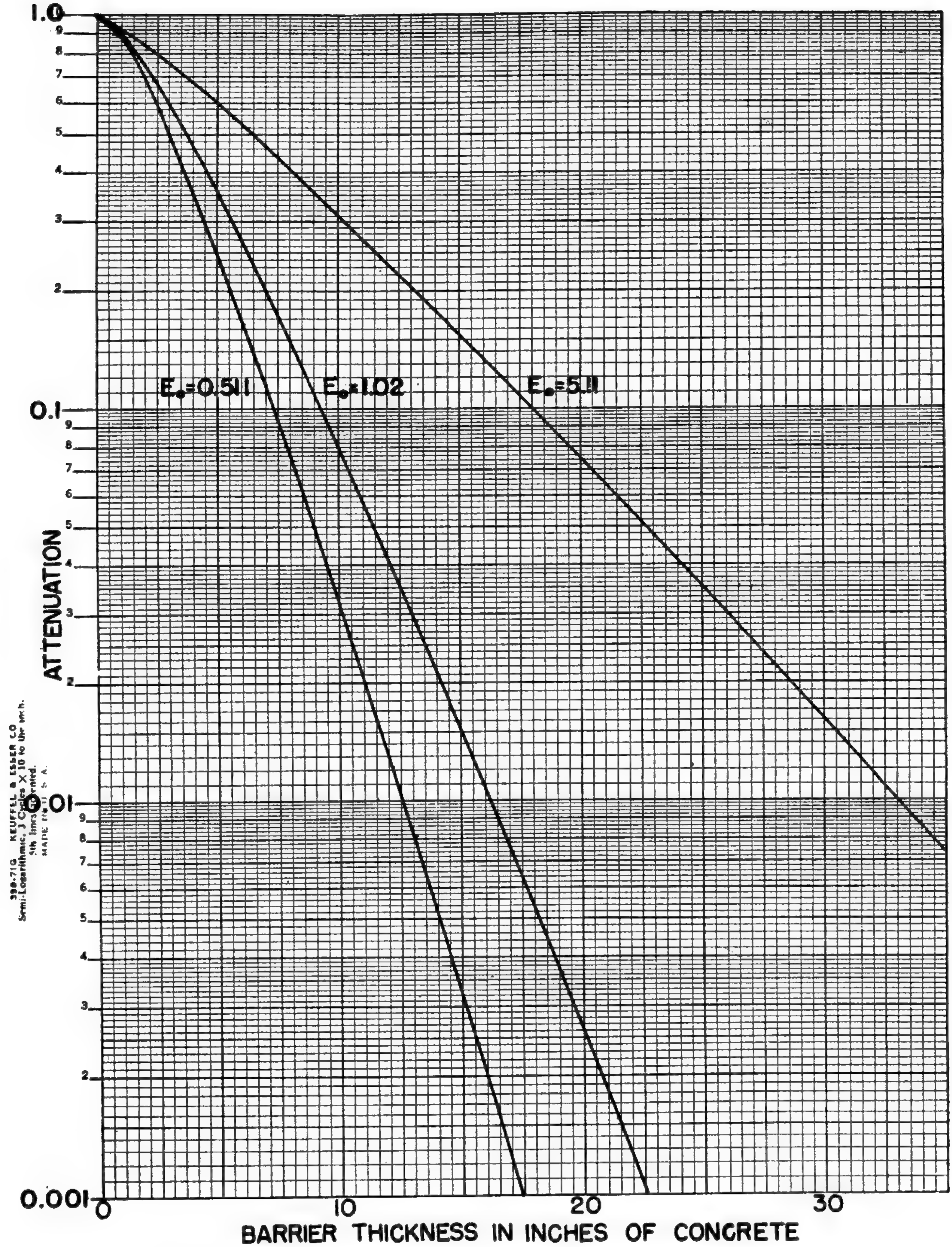


FIGURE 4.—Attenuation of gamma radiation dose as a function of concrete barrier thickness for three different gamma ray source energies. The units of E_o are Mev. The curves were calculated for gamma radiation perpendicularly incident on the barrier

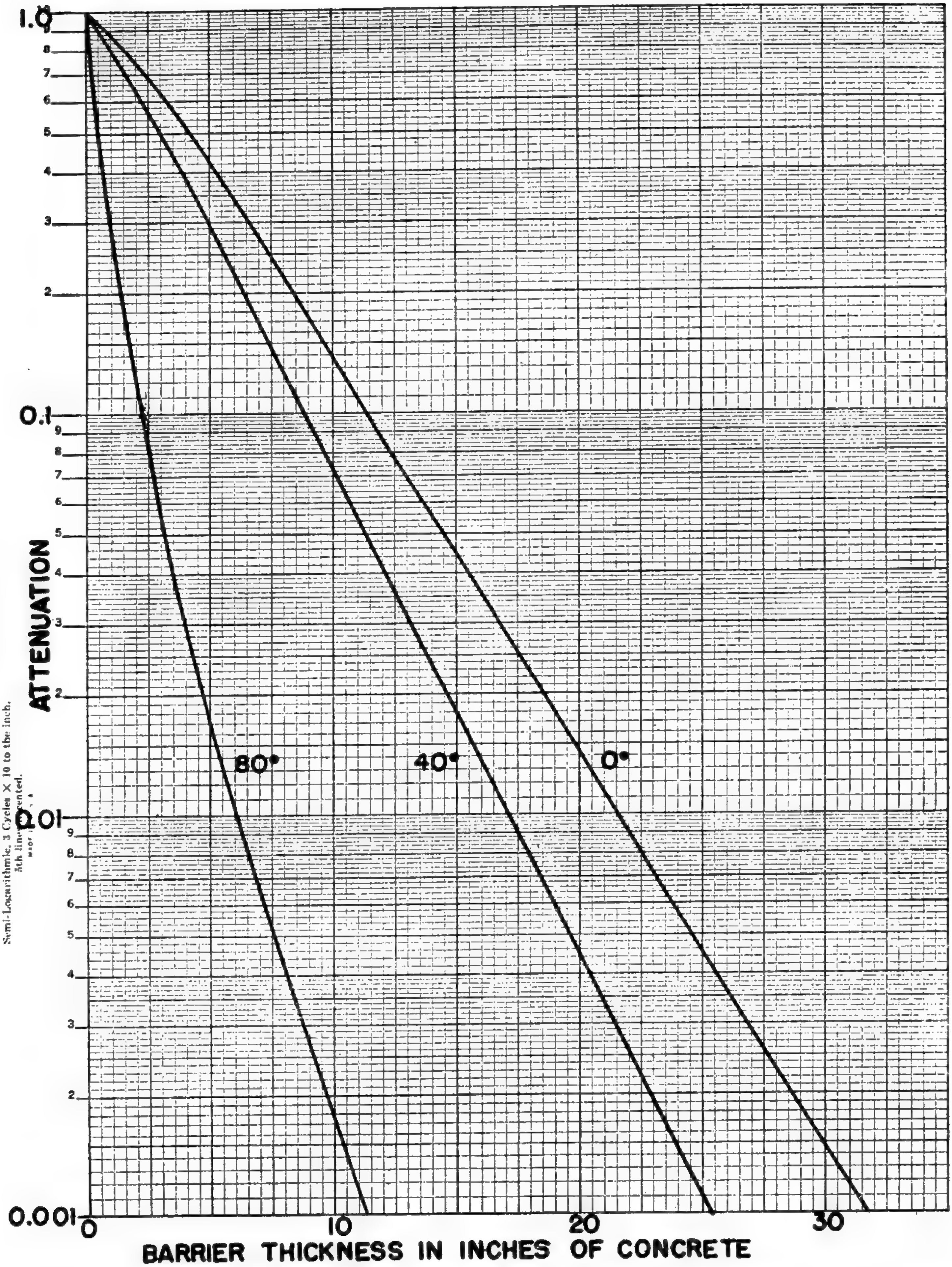


FIGURE 5.—Attenuation of gamma radiation dose as a function of concrete barrier thickness for three different angles of incidence. The curves were calculated for the energy distribution of fission product gamma rays at 1 hour after weapon burst.

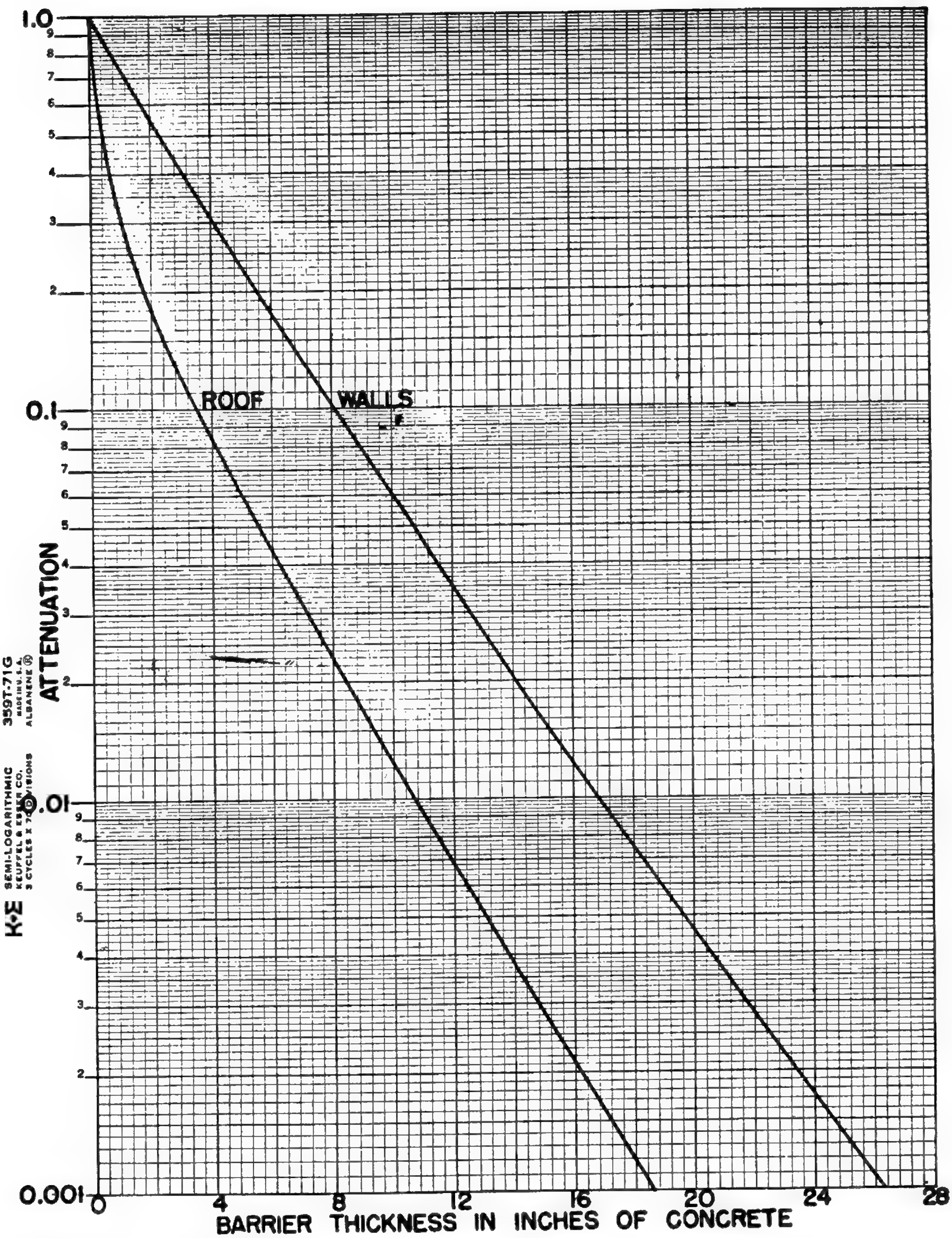


FIGURE 6.—Attenuation of gamma radiation dose as a function of concrete barrier thickness. The curve labeled "roof" gives attenuation of radiation from roof sources as it penetrates the roof and floors. The curve labeled "walls" gives the attenuation of radiation from ground sources as it penetrates the walls. Both curves were calculated for the energy distribution of fission product gamma rays at 1 hour after weapon burst.

Shielding calculations have been made for the combination of angles corresponding to radiation from fallout on the roof and radiation from fallout on the surrounding ground. Attenuation curves for the two types of sources are shown in figure 6. Although these curves were calculated for the energy distribution of 1-hour fission products, the qualitative differ-

III. NATIONAL ACADEMY OF SCIENCES ADVISORY COMMITTEE ON CIVIL DEFENSE, SUBCOMMITTEE ON RADIATION SHIELDING

In the problem of shielding from fallout radiation, as well as in all scientific work, it is important that the theoretical and the experimental work be closely coordinated. With this in mind, the Advisory Committee on Civil Defense of the National Academy of Sciences formed a Subcommittee on Radiation Shielding. This subcommittee is composed of people who are actively engaged in either calculations or experiments. It includes representatives from the Office of Civil and Defense Mobilization, the National Bureau of Standards, Oak Ridge National Laboratory, the Defense Atomic Support Agency, the Naval Radiological Defense Laboratory, Technical Operations, Inc., and the University of California. It was formed last October and has met approximately once every 3 months. This subcommittee also serves in an advisory capacity to OCDM in directing its research efforts on radiation shielding.

TABLE 1.—*Categorization of shelter areas*

Category	Protection factor	Typical examples
A	1,000 or greater	1. OCDM underground shelters. 2. Subbasements of multistory buildings. 3. Underground installations (mines, tunnels, etc.).
B	250 to 1,000	1. OCDM basement fallout shelters (heavy masonry residences). 2. Basements (without exposed walls) of multistory buildings.
C	50 to 250	1. OCDM basement fallout shelters (frame and brick veneer residences). 2. Central areas of basements (with partially exposed walls) of multistory buildings. 3. Central areas of floors near midheight of large multistory buildings with heavy exterior walls and floors.
D	10 to 50	1. Basements (without exposed walls) of small 1- or 2-story buildings. 2. Central areas of floors near midheight of large multistory buildings with light exterior walls and floors.
E	2 to 10	1. Basements (partially exposed) of small 1- or 2-story buildings. 2. Central areas of lower floors in large multistory buildings. 3. Central areas on ground floor in 1- or 2-story buildings with heavy masonry walls.
F	1½ to 2	1. Aboveground areas of low buildings, in general, including residences stores, factories, etc.

TABLE 2.—*Shielding factors in some typical light residential structures* [1]

[Values deduced from experiment]

Structure	Location	Reduction factors [2]: Roof contribution	Reduction factors [2]: Ground contribution	Reduction factors [2]: Total	Protection factor [3]
2 story wood frame house	2d floor center	0.076	0.50	0.58	1.7
	1st floor center	.034	.57	.60	1.7
	Basement center	.015	.028	.043	[4] 23
1 story wood rambler	1st floor center	.10	.54	.64	1.6
2 story brick veneer house	do	.034	.14	.17	[5] 6
	Basement center	.015	.021	.036	[4] 28

[1] Values in this table are from an NBS report, to be published. (Ref. 17.)
[2] Reduction factor is defined as dose rate at the specified location divided by the dose rate outside at 3 feet above the ground.
[3] Protection factor is defined as dose rate at 3 feet above the ground, outside, divided by the dose rate at the specified location.
[4] This factor applies to basements with no exposed walls.
[5] This factor applies only for detector locations below window sill level

BIBLIOGRAPHY OF REPORTS ON STRUCTURE SHIELDING

Experimental data

1. J. A. Auxier, et al., "Experimental Evaluation of the Radiation Protection Afforded by Residential Structures Against Distributed Sources," CEX–58.1, January 1959.

2. F. Titus, "Penetration in Concrete of Gamma Radiation From Fallout," NBS Report 6143, September 1958.

3. J. R. Cunningham, et al., "Protection Factors for Houses Using Radioactive Sources," Report DRCL–260, November 1957.

4. R. T. Graveson, "Radiation Protection Within a Standard Housing Structure," Report NYO–4714, November 1956.

5. A. G. McDonald, "The Penetration of Gamma Radiation From a Uniform Contamination Into Houses—A First Report on Some Field Trials," Report CD/SA–69 (home office), January 1956.

6. N. G. Stewart, et al., "The Shielding Provided by a Brick House Against the Gamma Radiation From a Uniformly Deposited Source. Experiments With Co^{60}," Report FWE–104, October 1955. (Official use only.)

Calculations

7. "Guide for Fallout Shelter Surveys" (preliminary edition), Executive Office of the President, Office of Civil and Defense Mobilization, Washington, D.C., April 1959.

8. R. R. Putz and E. Kuykendall, "A Comparison of Computed and Experimentally Observed Intensity Levels for Various Gamma Radiation Source Distributions and Shielding Conditions in Residential Structures," University of California, Institute of Engineering Research, February 1959.

9. R. R. Putz and A. Broido, "A Computation Method for Gamma Radiation Intensity in the Presidence of General Shielding and Source Configurations," Institute of Engineering Research, University of California, December 1957.

10. "A Method for Evaluating the Protection Afforded by Buildings Against Fallout Radiation" (draft), Executive Office of the President, Office of Defense Mobilization, September 1957.

11. C. W. Malich and L. A. Beach, "Radiation Protection Afforded by Barracks and Underground Shelters," Report NRL–5017, September 1957.

12. C. W. Malich and L. A. Beach, "Fallout Protection Afforded by Standard Enlisted Men's Barracks," Report NRL–4886, March 1957.

13. Bureau of Yards and Docks, "Studies in Atomic Defense Engineering," Report NAVDOCKS–P–290, January 1957.

14. Home Office, Scottish Home Department, "Assessment of the Protection Afforded by Buildings Against Gamma Radiation from Fallout," May 1957. (Official Use Only.)

Reports to be published

15. L. V. Spencer, "Shielding from Fallout Radiation," OCDM publication.

16. "Design and Review of Structures for Protection from Fallout Gamma Radiation," Executive Office of the President, Office of Civil and Defense Mobilization.

17. C. Eisenhauer, "Analysis of Experiments on Light Residential Structures With Distributed CO^{60} Sources", NBS report.

18. J. F. Batter, Jr., A. Kaplan, Eric T. Clarke, "An Experimental Evaluation of the Radiation Protection Afforded by a Large Modern Concrete Office Building," Technical Operations Inc., Report TOB–59–5.

19. E. T. Clarke, J. F. Batter, Jr., A. Kaplan, "Measurement of Attenuation in Existing Structures of Radiation From Simulated Fallout," Technical Operations Inc., Report TO5–59–4.

NBS reports on penetration of gamma radiation

20. L. V. Spencer and J. C. Lamkin, "Slant Penetration of Gamma-Rays: Mixed Radiation Sources," NBS 6322, February 1959.

21. M. J. Berger and D. J. Raso, "Backscattering of Gamma Rays," NBS 5982, July 1958.

22. L. V. Spencer and J. C. Lamkin, "Slant Penetration of Gamma-Rays in H_2O." NBS 5944, July 1958.

23. A. T. Nelms and J. W. Cooper, "U^{235} Fission Product Decay Spectra at Various Times After Fission," NBS 5853, April 1958.

24. M. J. Berger and J. C. Lamkin, "Sample Calculations of Gamma-Ray Penetration into Shelters: Contributions of Skyshine and Roof Contamination." NBS 5297, May 1957.

25. J. H. Hubbell, "Dose Due to Distributed Gamma Ray Sources," NBS 4928, November 1956.

Representative HOLIFIELD. Are there any questions? Congressman Hosmer?

Representative HOSMER. No, sir.

Representative HOLIFIELD. Thank you very much, sir, for your presentation.

The meeting of the committee will be in this room in the morning. It has been previously announced publicly that we will go to the Supreme Court room, but we have been fortunate enough to obtain this larger room so we will have our hearings tomorrow in this room.

Our first witness tomorrow morning will be Mr. Myron Hawkins, of the civil defense research project, University of California. There will be more testimony on the behavior of radioactive deposits. Then there will be a roundtable discussion on the basic properties and effects of radioactive fallout in which Dr. Paul Tompkins, Dr. Terry Triffet, Mr. Myron Hawkins, Mr. Joe Deal, Mr. Charles Shafer, Dr. Lester Machta, and Dr. Ralph Lapp will take part. Following that we will start in on the biological effects, and we have a number of witnesses on the biological effects.

The committee stands adjourned.

(Thereupon at 4:45 p.m., Monday, June 22, 1959, a recess was taken until Tuesday, June 23, 1959, at 10 a.m.)

most difficult problems are those associated with applying the theory to specific situations. The applications of theory to generalized environmental conditions in a valid manner is even more difficult. Many of the variables that must be considered in practical applications are not well defined and described. One example of this uncertainty is the characteristics of the fallout material. It is obvious that if we are to predict the behavior of fallout around terrain features accurately, we must be able to describe the fallout material. However, as Dr. Triffett has mentioned, the size of the radioactive particles may vary considerably for different types of detonations (5). For instance, if the detonations are in deep water the particles will generally be small, whereas if the detonations are on sandy soil, a wide variety of sizes will be produced with the mean particle size being larger than that from a sea-water detonation. Intermediate conditions may occur with detonations in harbors or on the surface of clay soils, and we do not know how to predict what sizes may occur. Another variation is related to the "stickiness" which is considerable for some types of fallout particles but negligible for others.

After the period of the initial cloud formation, the particles resulting from the detonation are acted on principally by two forces: gravity and the force of the wind. The following table indicates the approximate angle from the horizontal at which fallout particles approach the surface of the earth.

TABLE I.—*Trajectory angles (in degrees from horizontal) for various size spherical particles (spgr.=3) in 70° F. air at sea level*

[In degrees]

	Particle size, microns			
	30	100	300	1,000
Horizontal wind velocity:				
5 knots	1⅔	13⅓	45	71
15 knots	½	4½	18½	44½
30 knots	¼	2¼	9½	26⅓

Only for the largest sizes and under very low wind speeds do the particles approach the earth at a steep angle. Otherwise, the angle of approach and contact with the earth is small.

As is well known, the wind patterns near the surface of the earth are modified by terrain features as well as by manmade structures (6). The air flows up, over, and around any obstruction. Small particles tend to follow the path of the air whereas the larger heavier particles tend to continue in their trajectory in spite of changes in the direction of airflow. This effect is, of course, related to inertia and if the change in air direction is gradual, there is a greater tendency for all of the particles to follow the air, although gravitational forces continue to influence the overall resultant trajectory.

Around very small objects, such as twigs and small branches, the changes in air direction are very sudden and even very small particles will impact on the objects. If the obstructions are somewhat larger, say up to the size of large buildings, the changes of air direction are less sudden, and we can expect only the larger particles to be impacted on the obstructions. The smaller particles will follow the air and not contact the obstruction. It should be noted that although a particle impacts on a vertical surface, it will not stay there unless the surface or the particle is "sticky" or the surface has near-horizontal irregularities, or the electrostatic forces are large. Dr. Corcos has summarized the impaction phenomena with some idealized examples:

(*a*) For terrain consisting of horizontal areas and solid vertical cylindrical obstructions about 5 feet in diameter, particles 75 microns and less in diameter will deposit only on horizontal surfaces and will not be impacted on the obstruction, except when the wind velocity exceeds 30 knots. Larger particles will impinge on the obstruction, with the amount of "catch" increasing with particle size.

(*b*) Similarly, if the solid obstruction is 100 feet in diameter, particles up to 350 microns in diameter will bypass the obstruction if the wind has a velocity of 10 knots or less.

The basic natural forces of prime importance in migration appear to be wind, rain, and waterflow.

All of us are aware of the general phenomena of soil erosion by wind. Dr. W. S. Chepil, of the Agricultural Research Service, has studied this phenomenon extensively (16, 17). Briefly, his conclusions are as follows:

(*a*) If a smooth surface of noncohesive soil is exposed to winds, particles in the size range 50 to 500 microns are highly erosible. Both larger and smaller particles are difficult to erode.

(*b*) If the area is sufficiently large, the erosive action of the 50-500 micron particles will dislodge smaller particles and break up the larger particles by impaction.

(*c*) The larger particles of eroded material will not travel far but will be redeposited generally in the surface depressions throughout the area; whereas the very small particles (i.e., less than 20 microns or so) that are "kicked up" by other particles may form dust clouds that are carried great distances from their source.

(*d*) Erodibility tends to decrease with increase in surface roughness and with the amount of vegetation present. The erosion of soil from a grassy plot is negligible.

(*e*) Only dry soils are moved by the wind.

(*f*) The lowest wind velocity that can produce soil erosion is 9 to 10 miles per hour (measured at a 12-inch height), and under field conditions, erosion usually does not become perceptible until the velocity exceeds 13 miles per hour.

These findings can be applied qualitatively to the erosion of fallout by wind as follows:

(*a*) One would expect the dry fallout to be eroded from tilled fields or fields with sparse vegetation in a manner similar to soil of the same particle size range. Similarly, dry fallout particles on paved areas would be blown to areas where the surface roughness, vegetation, and obstructions trap them more permanently. If the areas are small, however, many of the very small and the very large particles may remain in place.

(*b*) Fallout on areas covered with vegetation will not appreciably be carried off by wind.

These conclusions are supported in general by others (10, 18, 19). Dr. Dunning (20) reports that the maximum radiation intensities from a narrow fallout pattern on the Nevada desert were reduced considerably by the action of strong winds. Such results are to be expected if the fallout path is narrow, e.g., that produced by a very small surface detonation.

The action of rain is much more complex. At the civil defense research project, we have studied this problem in connection with hazards of fallout in water supplies (21, 22). Fallout from a detonation on a land surface tends to separate into three parts upon contact with water: settleable solids (particles larger than 0.1 micron in size), nonsettleable insoluble colloids (particles between 0.001 and 0.1 micron in diameter), and soluble materials. It is primarily important to know the fraction of radioactive material associated with each part. If fallout lands on a body of water, the basic separation takes place rapidly (23). Subsequently, the large particles may settle out but the solubles and colloids tend to follow the water unless some physical action removes them.

Unfortunately, we know very little about how to predict for any given fallout deposit what fraction of the radioactive material is in each of the three parts. The information we do have is meager. It appears, however, that about half of the radioactive material in the fallout from a detonation in deep sea water is of the soluble or colloidal variety (5). If this is the case, it is largely in a form that after deposition would adsorb on soil or vegetation. The close-in fallout from surface and underground detonations in Nevada appears to have less than 2 or 3 percent of the radioactive material in a soluble form (5), although some fallout fractions collected at greater distances from the detonation by Dr. Larson's group have been "soluble" to the extent of 40 percent (7). It has been reported that the long-range fallouts landing on Great Britain is about 50 percent "soluble" (24).

If the detonations occur on or near the surface of clay soils (which are common in the United States), we cannot predict the size distribution or solubility of fallout with any degree of reliability (5). Most of the following dis-

Engineering Research, University of California. Series 2, issue 20. (In preparation.)

3. Read, R. R.: "Interim Report: Technique for Designing and Employing a Radiological Monitoring System for the Event of Attack." Civil Defense Research Project, Institute of Engineering Research, University of California. Series 2, issue 22. (In preparation.)

4. Corcos, G. M.: "On the Small-Scale Non-Homogeneity of Fallout Deposition." Civil Defense Research Project, Institute of Engineering Research, University of California. Series 2, issue 2, October 30, 1958.

5. Triffett, Terry: USNRDL, personal communication, June 1959.

6. "Meterology and Atomic Energy." Atomic Energy Commission, AECU-3066, July 1955.

7. Nishita, H. and K. H. Larson: "Summary of Certain Trends in Soil-Plant Relationship Studies of the Biological Availability of Fall-Out Debris." UCLA-401, July 18, 1957.

8. Brittain, R. W.: "The Effect of Plant Surfaces on Pesticidal Dust Deposition." Thesis, Michigan State College, 1954.

9. Langbein, W. B. et al.: "Annual Runoff in the U.S." U.S. Geological Survey Circular No. 52, June 1959.

10. Machta, L. and K. M. Nagler: "Meteorology—Fallout and Weathering." In "Symposium—The Shorter Term Biological Hazards of a Fallout Field," AEC-DOD. U.S. Government Printing Office, Washington, D.C.

11. Broido, A. and A. W. McMasters: "The Influence of a Fire Induced Convection Column on Radiological Fallout Patterns." Civil Defense Research, Institute of Engineering Research, University of California. Series 2, issue 13, February 2, 1959.

12. Sheffield, E. T.: "Buffer Zones Required in the Reclamation of Radiologically Contaminated Areas." USNRDL-TR-31, January 1955.

13. Ksanda, C. F., A. Moskin and E. S. Shapiro: "Gamma Radiations from a Rough Infinite Plane." USNRDL-TR-108, January 18, 1956.

14. "Proceedings of the Shielding Symposium Held at the U.S. Naval Radiological Defense Laboratory, October 17-19, 1956. USNRDL-RL-29, February 1, 1957.

15. Hill, J. E.: "Effects of Environment in Reducing Dose Rates Produced by Radioactive Fallout from Nuclear Explosions." Rand Corp., RM-1285-1, September 28, 1954.

16. Chepil, W. S.: "Soil Conditions that Influence Wind Erosion." USDA Technical Bulletin No. 1185, June 1958.

17. Chepil, W. S. and N. P. Woodruff: "Estimations of Wind Erodibility from Farm Fields." USDA Agricultural Research Service, Product Research Report No. 25, March 1959.

18. Hilst, G. R.: "Measurements of Relative Wind Erosion of Small Particles from Various Prepared Surfaces." HW-39356, October 5, 1955.

19. Healy, J. W. and J. J. Fuquay: "Wind Pickup of Radioactive Particles from the Ground." Second U.N. Conference on the Peaceful Uses of Atomic Energy, A/Conf. 15/P/391, June 1958.

20. Dunning, G. M.: "Radiations from Fallout and their Effects," in "The Nature of Radioactive Fallout—," p. 170, JCAE, 1957.

21. Kaufman, W. J. and H. F. Dennin: "Interim Report on Radiological Defense of Water Utilities." University of California Project "Civil," April 15, 1957.

22. Hawkins, M. B.: "Summary of Problems Relating to Local Fallout Contamination of Water Supplies." Civil Defense Research Project Institute of Engineering Research, University of California. Series 2, issue 14, February 24, 1959.

23. Lowe, H. N., Jr., et al.: "Solubility Characteristics of Radioactive Bomb Debris in Water and Evaluation of Selected Decontamination Procedures." ERDL, February 1959.

24. Medical Research Council (Great Britain): "The Hazards to Man of Nuclear and Allied Radiations," London, 1956.

25. Hoyt, W. G. and W. B. Langbein: "Floods." Princeton University Press, 1955.

26. Duley, F. L. and L. L. Kelly: "Effect of Soil Type, Slope and Surface Conditions on the Intake of Water." University of Nebraska, Agricultural Experimental Station Research Bulletin No. 112, May 1939.

27. Whittaker, J. R. and E. A. Ackerman: "American Research." Harcourt, 1951.
28. Hawkins, M. B. and W. S. Kehrer: "Feasibility and Applicability of Roof Washdown Systems." USNRDL–TR–232, May 7, 1958.
29. Ellison, W. D.: "Soil Erosion Studies," parts I–VI. Agricultural Engineer, vol. 28, No. 4–10, pp. 145–146, 197–201, 245–248, 297–300, 349–351, 402–408, 442–450, April–October 1951.
30. Straub, C. P., and L. R. Setter: "Distribution of Radioactivity from Rain." Transactions, American Geophysical Union, vol. 39, pp. 451–458, July 1958.
31. "Report of the Joint Program of Studies on the Decontamination of Radioactive Waters." ORNL–Taft S.E.C., ORNL–2557, February 9, 1959.
32. Lacy, W. J.: "Removal of Radioactive Fallout from Contaminated Water Supplies," "The Nature of Radioactive Fallout—," p. 2054–2058, JCAE, 1957.
33. Baum, S.: "Adherence of Fallout to Trees and Shrubs." Enclosure to letter, USNRDL to OCDM, January 20, 1959.

Mr. Hawkins. If, for instance, we have an object sitting on the surface of the ground and the wind is blowing, the wind will pass around either side of such an object. The amount of material that is impacted on the front surface is dependent primarily on the size of the particles, the speed of the wind, and the size of the object. If the object itself is a small twig the wind patterns will pass around it like so (fig. II). The wind may be highly turbulent on the lee side. Very small particles tend to follow the airflow closely. A large particle because of its inertia is not going to turn the corner and may be cast out by "centrifugal" force, and be impacted on the surface of such an object. If the objects are very small (in dimension A), say the size of twigs, these changes in wind direction are very sudden and even very small particles may impact a twig.

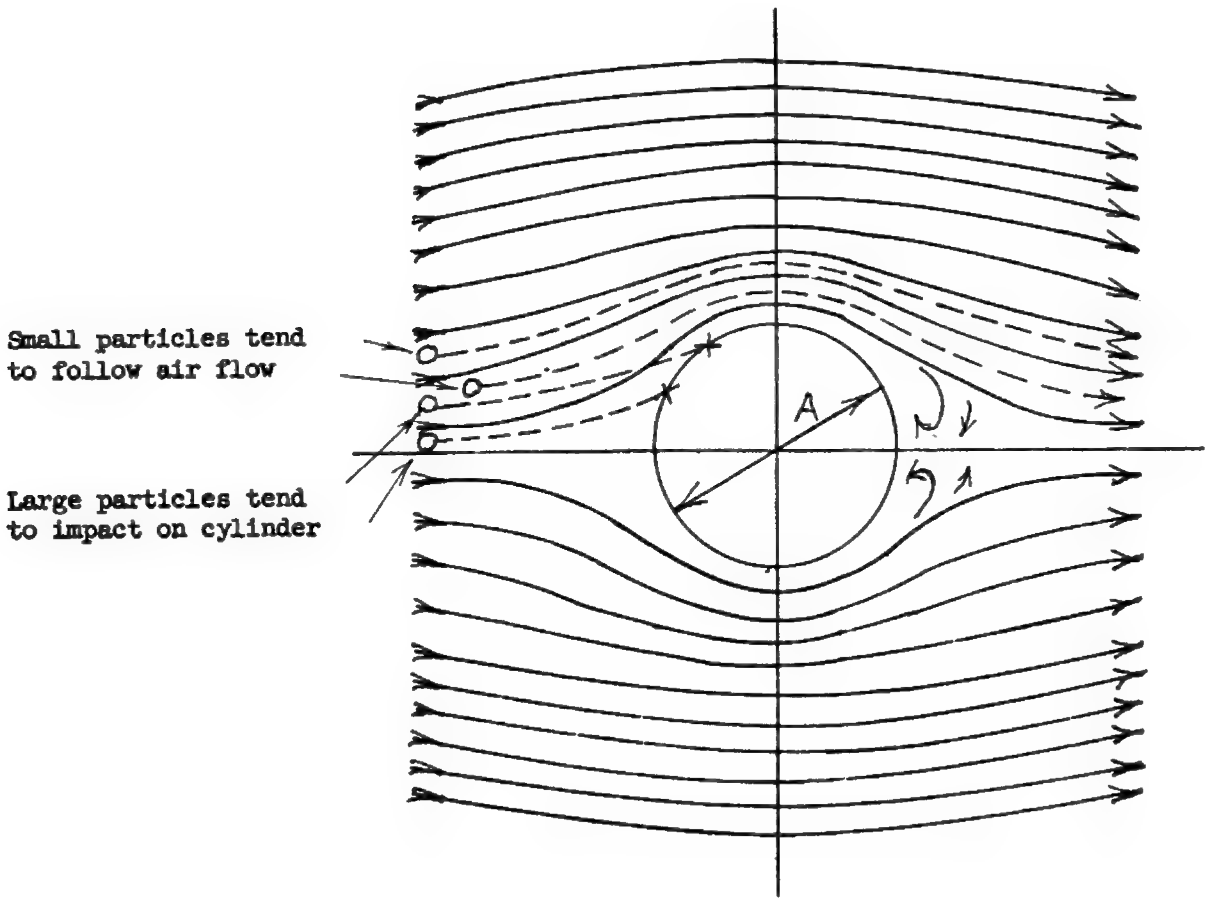


Figure II

Idealized pattern of air flow around a cylindrical object, plan view.

Basic Properties and Effects of Radioactive Fallout

FACTORS MODIFYING THE BEHAVIOR OF DEPOSITED CONTAMINANTS

(By Sanford Baum,[1] U.S. Naval Radiological Defense Laboratory)

Estimates of the radiological hazard caused by the fallout from megaton-range weapons are usually obtained either from measurements carried out in the Pacific or by the application of fallout prediction methods. In general, neither of these sources involves direct measurement of fallout which is actually deposited on a land surface. In the case of measurements from the Pacific area, most of the fallout is deposited in the ocean. It is necessary to reconstruct, from measurements of the activity left near the ocean surface, the radiation contours which would have resulted had the same deposition occurred over land. Descriptions of the hazard produced by megaton weapons must contain an assumption about the land surfaces over which fallout is expected to occur. The assumption most frequently made is that the fallout producing the hazard in a given locality is uniformly distributed over an infinitely large plane. Occasionally, this assumption is modified to take the roughness of the terrain into account. A second assumption is that, once the fallout is deposited on the plane, it remains fixed and the only changes in radiation intensity are due to radioactive decay.

When potential targets in the United States are considered, neither of these assumptions is necessarily justified. The targets contain both natural and man-made objects which obviously depart from the conditions of the first assumption. Wind, rain, or snow can either move the deposited contaminant or cover it with inert material such as snow or sand. It is recognized that all of these factors can modify the predicted degree of hazard.

The effect of weather on the deposited contaminant has been discussed by Machta and Nagler (1). Fallout particles in the atmosphere may be trapped in rain or snow. Once they reach the ground they can be washed into the ground or carried away by runoff. The latter effect is more important usually, because, once the airspaces in the ground are filled with water, most of the additional water will run off into streams, carrying along more of the radioactive particles.

Fallout deposited in the dry form can be affected by rain or snow. Significant transport will result when raindrops dislodge particles in strong winds or on slopes with as little as 10-percent grade. The winds can move the particles directly. The primary factor here is size of the fallout particle. Particles whose diameters range from 50 to 500 microns are the most easily moved. In areas of significant hazard particles in this range are responsible for most of the radiation (2). In general, the movement of these particles will result in a net lowering in the regions of high intensity and some extension of the fringe areas.

There is little quantitative information on these topics. Qualitative evidence which, in the main, supports the above conclusions have been described by Strope (3). The problem is complicated because of the variability in the meteorological parameters. In general, the effect of weather is to reduce the predicated intensities.

Experiments to determine the change in hazard caused by gross differences in natural terrain have been performed. Equal amounts of a radioactive isotope were placed in an identical manner on equal areas with varying degrees of roughness. The roughness ranged from that of a smooth concrete slab to that of a wooded hilly field. It was found that the hazard decreased with increasing roughness. At the standard height of 3 feet, the radiation from the roughest surface was two-thirds that of the smoothest. Differences caused by varying surfaces of measurement tend to disappear with increasing height. Comparisons have been made between a fallout-contaminated Nevada area and computed results based on the flat plane assumption (5). It was found that in the real case, the deposited fallout behaves as if it were uniformly mixed to some shallow depth, of the order of an inch, in the soil. This implies that the flat plane value will be too high (4, 5, 6). Another consequence of this difference is that in an

[1] Chemist, Military Evaluations Division, U.S. Naval Radiological Defense Laboratory, San Francisco, Calif. Date of birth: Oct. 22, 1924. Married: Two children. Education: B.S. in chemistry, University of California, 1951.

area partially free of fallout, the radiation intensity first increases and then decreases as the height of measurement over the cleared area increases. The latter consequence is of importance in considering the shelter afforded by multistory buildings. Comparisons between calculated values obtained on the basis of the infinite plane and observed radiation intensities were possible for one event and location in the Pacific (7). It was found that the ratio of observed to calculated intensities varied with time. Ratios of 0.45, 0.66, and 0.56 were found at 11.2, 100 to 200, and 370 to 1,000 hours, respectively.

The role of vegetation and trees, which could in effect elevate some of the fallout above the surrounding ground level, has been examined by Baum (8). It was concluded that the amount of radiation contributed by the fallout attached to vegetation or trees would be small when compared to that emanating from the ground. This situation was considered by Lindberg (9), whose work (10, 11) in Nevada, provided much of the data used by Baum. Lindberg also concluded that the contribution from contaminated plants would be small. It was recognized by all concerned that rather large extrapolations were required to reach the conclusion and that more direct evidence was desirable.

When the fallout occurs over a community, a number of departures from the infinite plane case are encountered. Part of the fallout that would have been deposited on the ground is now resting on roofs. This has the effect of reducing the predicted intensity by (1) placing the fallout a greater distance away from the standard measuring point near the ground, and (2) interposing material between the fallout and the measuring point. Walls interpose material between the measuring point and fallout deposited on streets and unpaved areas. The reductions achieved are dependent on the dimensions and composition of the structures and in their placement relative to one another. Methods for predicting these reductions have been published (12, 13, 14). An indication of the effect of adjacent structures, in heavily built-up urban areas, is given by the following numbers. The values listed are the reductions in intensity in an area adjacent to one or more streets.

Number of adjacent streets	1	2	3	4
Reduction of predicted intensity	0.2	0.3	0.4	0.5

Application of these numbers should be made with discretion and only after reference to the original source (12). This requirement holds for all such numbers.

In the presence of even moderate winds, vertical surfaces such as walls introduce an additional perturbation. Under these conditions more particles are, in essence, flowing toward the walls than are falling to the ground. In spite of this fact, it has been observed that the ratio of horizontal to vertical contamination may vary between 5 to 1 and 300 to 1 (3). Either the particles strike the vertical surfaces and then fall to the ground at its foot, or because of airstream effects, the particles flow around the vertical surfaces. Comparisons have been made (3) between the contamination found on horizontal surfaces at the head and foot of vertical surfaces. No significant differences were found. The investigation also found that there were no differences between the front and back sides of vertically oriented surfaces. These observations can be explained on the basis of flow around the surfaces. A theoretical study of airstream phenomena has been published (15). It predicts that 75-micron particles will deposit only on horizontal surfaces and that inhomogeneites will occur rarely and over small areas. Inhomogeneites in deposition are expected to occur with particles around the 350-micron size. The most common effect will be a decrease in deposition on the roof and lee of large buildings. No upper limit can be set on the maximum concentration which may be found under adverse circumstances. It has been reported that the best available estimate of the range of significant particle sizes in areas of hazardous fallout is 50 to 400 microns (2).

Most of the experimental evidence quoted was obtained under the conditions that exist at the test sites. Extrapolation to U.S. targets involves the deposition of a possibly different contaminant into an environment very unlike that encountered at the sites. Hopefully, the difficulties inherent in the latter circumstance can be surmounted by investigations now underway at NRDL or elsewhere. Lack of knowledge concerning the basics of the fallout formation process, precludes any definitive statement about the probable nature of the fallout from U.S. targets. Consequently the extrapolation cannot be performed with confidence. Within this limitation, it has been found that the overall effects of terrain and weather reduce the hazard predicted on the basis of current assumptions.

REFERENCES

1. Proceedings from the symposium on "The Shorter-Term Biological Hazards of a Fallout Field," edited by Dunning, G. M. and Hilcken, J. A.; Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. (December 12–14, 1956).

2. Baum, S. "Current Status of Contaminant Phenomenology" USNRDL report in final preparation for OCDM.

3. Earl, I. R., et al. "Protection and Decontamination of Land Targets and Vehicles," project 6.2, Operation Jangle, WT–400 AFSWP (June 1952) secret, R.D.

4. Mahoney, J. J., and Price, R. B., "Experimental Tests of Shielding and Attenuation of Gamma Radiation From Radioactive Tantalum Versus Infinite Plane Theory," CRLIR–94 (January 1952) secret, R.D.

5. Ksanda, C. F., et al. "Gamma Radiations From a Rough Infinite Plane," USNRDL–TR–108 (January 1956).

6. Ksanda, C. F., et al. "Gamma Radiations From Contaminated Planes and Slabs," USNRDL–TM–27 (January 1955).

7. Triffet, T., and La Rivere, P. D., "Characterization of Fallout," volume I, project 2.63, Operation Redwing, final report in review by AFSWP (August 1958), secret.

8. FF letter to OCDM, from CO, USNRDL, "Adherence of Fallout to Trees and Shrubs," WES: 910 (January 1959).

9. Letter to OCDM, from R. G. Lindberg, University of California Medical Center, Department and Laboratories of Nuclear Medicine and Radiation Biology, Los Angeles, Calif., dated March 26, 1959.

10. Lindberg, R. G., et al. "The Factors Influencing the Biological Fate and Persistence of Radioactive Fallout," Operation Teapot, ITR–1177 (August 1955), confidential, R.D.

11. Lindberg, R. G., et al. "Environmental and Biological Fate of Fallout From Nuclear Detonations in Areas Adjacent to the Nevada Proving Grounds," Operation Upshot-Knothole, WT–812 (February 1954) confidential, R.D.

12. "Guide for Fallout Shelter Surveys, Interim Edition," Office of Civil and Defense Mobilization, Battle Creek, Mich. (February 1959).

13. "Radiological Recovery of Fixed Military Installations, Interim Revision," TM 3–225 or NAVDOCKS–TP–PL–13, Departments of the Army and the Navy (April 1958).

14. "A Method for Evaluating the Protection Afforded by Buildings Against Fallout Radiation," Office of Defense Mobilization, Washington, D.C. (September 1957).

15. Corcos, G. M., "In the Small-Scale Nonhomogeneity of Fallout Deposition" University of California, Institute of Engineering Research, Berkeley, Calif. (October 1958).

Representative HOLIFIELD. At this time I will ask the panel members to come forward.

ROUND TABLE PANEL DISCUSSION ON THE BASIC PROPERTIES AND EFFECTS OF RADIOACTIVE FALLOUT

Participants: Dr. Paul Tompkins, Naval Radiological Defense Laboratory; Dr. Terry Triffet, Naval Radiological Defense Laboratory; Mr. Myron Hawkins, civil defense research project, University of California; Mr. Charles Shafer, Office of Civil Defense Mobilization; Dr. Lester Machta, U.S. Weather Bureau; Mr. L. Joe Deal, Division of Biology and Medicine, AEC; and Dr. Ralph Lapp, independent physicist.

Representative HOLIFIELD. The panel has been convened in an effort to clarify and consolidate an understanding of the specific technical points upon which an agreement exists and a clarification of those areas in which disagreement is apparent. In line with the committee's objective in bringing before the public, in an understandable

MYRON HAWKINS:

of the induced radiation in uranium 238. We can refer to a British report which indicates that around 60 percent of the total activity at 4 days—activity in this case is the number of disintegrations—is due to the uranium 239 and neptunium 239 that are produced, as the British say, in either large or small weapons. I believe part of the hump on the curves in the early times, say around 4 days, is largely due to this. The neptunium does not have extremely energetic radiations so that the radiation intensity is not quite proportionate to the disintegration. But, nevertheless, it does have a significant influence at those times.

Representative HOLIFIELD. It seems to me this makes a great deal of difference in the protection of survivors in case of nuclear attack. The accumulation of roentgens being more intense at first, if shelter or shielding could be provided from those effects for the immediate intense period, then there would be lesser danger in the latter 6 months of the year or in the following year. Is this not true? I am going to get back now to Mr. Shafer because I know he has something to say.

Mr. SHAFER. Thank you, Mr. Chairman. I would like to point out actually the degree of difference with regard to what Dr. Lapp discussed and what $t^{-1.2}$ would indicate.

Dr. Lapp indicated that with his assumption the dose during the first 24 hours, with an initial dose rate of 2,500 roentgens per hour at H plus one, would be 8,150 roentgens. The $t^{-1.2}$ indicates that the dose during the first day would be 6,000 roentgens. This is 6,000 versus 8,150. That is not much of an increase, but this is not the main point I am bringing up. The point I am emphasizing is that within OCDM we are well aware of these uncertainties. This is why we have recommended a shielding factor much greater than would be required based on the $t^{-1.2}$ assumptions.

With regard to the latter part of the spectrum, the period subsequent to 2 weeks, you will recall that I stated yesterday, Mr. Chairman, we have little confidence in the dose calculations indicated on the 3-month chart. We showed an increase between 2 weeks and 3 months of about 2,000 roentgens in the most intense area. In these time periods beyond 2 weeks I stated that we had very little confidence in any dose computations and perhaps in lieu of 2,000 this dose might well be as low as 1,000 roentgens during the period from 2 weeks to 3 months. We are fully cognizant of these uncertainties, sir, and take them fully into account in our OCDM survival and recovery planning.

Representative HOLIFIELD. Did you have any comment on that, Dr. Tompkins?

Dr. TOMPKINS. I think, Mr. Holifield, the main point I wanted to bring out is that the application of this type of information since 1957 has improved to the point where one should recognize openly that the $t^{-1.2}$ law is not a basic law. It is an approximation. As long as people understand it is an approximation and use it correctly and intelligently, this will be all right.

Representative HOLIFIELD. This is why, if I had been in Mr. Shafer's position, I would have said, according to the data of 3 years ago, this is the reading we have, but according to newer data it may be twice that much. Then we would have had figures, I think, which would more approximate the new data.

Dr. TRIFFET. Yes. I thought this might be an appropriate place to comment on the variation of the average energy. It is clear when you think of shielding, because the effectiveness of shielding depends directly on the average energy radiation from the deposited material. As I mentioned, Dr. Cook at our laboratory has done quite a bit of work on this. What it amounts to is that at one hour the average energy is about one Mev. This appears, by the way, in the tables that are in my written statement but that I did not present orally.

Representative HOLIFIELD. Mev. means?

Dr. TRIFFET. Million electron volts. At 2 hours it drops to 0.95. At a half day, to 0.6. At 1 week it drops to 0.35. Then it begins to go up again. At 1 month, it is 0.65, 2 months 0.65. The meaning of this is simply that there is a period around 1 week when if induced products are important in the bomb, there are a lot of radiations emanating from these, but the energy is low so it operates to reduce the average energy in this period and shielding is immensely more effective.

Representative HOLIFIELD. Did you have an additional comment on that, Dr. Lapp? ← LAPP TRYING TO GET MORE DATA!

Dr. LAPP. I think you would not include sodium in that category.

Dr. TRIFFET. No. This is an environmental effect. The activity I was referring to is an induced activity in the weapon.

Representative HOLIFIELD. I believe it was testified yesterday that the buildings 25 miles away would suffer a great deal of glass damage from a 10-megaton weapon. In view of the fact that we have several million schoolchildren in schools throughout the Nation and most of these schools have a very high percentage of exterior walls and glass, will not this constitute, within itself, one of the great hazards in this type of war? I am thinking of the areas that are far removed, as far as 15 or 25 miles, from the immediate blast damage in the central area.

Would this not constitute a tremendous damaging factor?

Mr. DEAL. Mr. Chairman, I might be stealing some of Dr. White's thunder, who is testifying on the blast problem this afternoon——

Representative HOLIFIELD. We will withhold that because we don't want to steal anybody's thunder. It is bad enough to steal their radioactivity. There is one factor we considered on all these different bombs. They have been surface bursts. The factor of extension of the heat of the fireball has been predicated upon the surface atmosphere, the close-to-ground atmosphere, the thickness or humidity or other qualities in the earth's atmosphere. Would there be a difference in a bomb exploded, let us say, 25 miles in the air. I am thinking of heat transference, or 40 miles in the air, as against the transference of heat along the ground level. If so, what would that factor of five be? We recognize that the air gets thinner as it goes up and there would be less resistance to heat transference. I think Dr. Shelton testified to that. He is not here today.

Is there anybody who would like to pick that up?

Dr. TOMPKINS. I will start in qualitatively, Mr. Holifield. I think what would happen is that as the altitude went up the increased fraction of the total energy going out in the thermal would increase the amount of heat generated.

because we can put a hole in it. The second thing that it does is that it gives maximum blast pressures. By being close to the ground it also maximizes the fallout radiation problems.

The attack pattern we have more or less evens out all of the effects and gives a good coverage of each.

Representative HOLIFIELD. From the standpoint of striking a balance, then, you would say that this attack pattern the committee has presented is a balanced attack pattern and takes into consideration most of these factors?

Dr. TOMPKINS. From the standpoint of the relative weapons effects it is a good balance. This is quite apart from any military characteristics.

Representative HOLIFIELD. Mr. Shafer, you had your hand up a moment ago.

Mr. SHAFER. With regard to irregularities of fallout deposition, Dr. Triffet showed yesterday an analysis of a multimegaton detonation in the Pacific in which there was a tremendous fanning out of the fallout with several hot spots.

I would like to make it clear to the committee that this particular type of wind behavior, such as exists in the South Pacific, is very typical as far as the United States is concerned. We do not have that type of wind behavior in the United States except possibly in the Gulf States in the summertime, only one season out of four. In the particular season we had under study, the fall season, October 17, 1958, the tropical easterlies did not exist anywhere in the United States and up to 60,000 feet altitude there were no easterlies even in the high stratospheric regions. So that the pattern which Dr. Machta showed would be more typical of what we could expect. But the primary thing that I want to point out is that in the event of an actual emergency we would not go through this theoretical approach to determine the location of fallout. We would do this by monitoring. To this effect we have distributed some 90,000 survey meters to the States and the local governments, some 60,000 to the Federal Government, and an additional 60,000 to the high schools. In the event of an emergency all of these 200,000 plus instruments would be used to rapidly monitor the fallout.

Representative HOLIFIELD. Are these mostly instruments that show radioactivity but do not quantitatively measure it?

Mr. SHAFER. They do both, sir. They detect it and indicate the dose rate in roentgens per hour, both gamma and beta discrimination and they indicate the accumulated dose.

Representative HOLIFIELD. How often are they calibrated, and are they dependable?

Mr. SHAFER. At the present time we are developing a calibration program. Some of the States, California, New York, and others are doing very well in calibrating their instruments. We are developing a calibration instrument using 20 curies of cesium 137 which will allow all of the States to calibrate their instruments. Further, our monitoring instruments are very dependable.

As you know, we do have before the Congress at the present time legislation to get sufficient funds to procure monitoring instruments. Additional instruments will be needed this year to set up some 37,000 monitoring points across the United States. We have asked for $8.5

the "Effects of Nuclear Weapons" must be looked upon as a practical lower limit.

Local fallout consists of relatively heavy debris which is deposited near the site of detonation within 1 day. The fission yield curve is characterized by high yields in the vicinity of mass numbers 85 to 100 and 135 to 145. In the first group of mass numbers there are many primary fission products belonging to the elements bromine and krypton, while in the other group iodine and xenon head up the fission chains. Strontium 90, for example, has 33-second krypton as its birth predecessor; cesium 137 derives from a fission chain headed up by 22-second iodine, followed by 3.9-minute xenon. Because of their volatile or gaseous ancestry in the fireball or bomb cloud a number of the high-yield fission products are formed in finely divided particles. Some of these are so small that they are not subject to gravitational settling, and in fact they remain suspended in the earth's atmosphere for many years, providing[6] that they reach the stratosphere at the proper latitude. In any event such fission products would be depleted in the local fallout. It is difficult to allow for this depletion since it depends upon the magnitude and mode of the detonation as well as upon local meteorology.

ADDITIONAL RADIOACTIVITY

Little attention has been given to the hazards presented by radioactive products produced in nonfission reactions in the bomb itself, or in the local environment. In the case of the bomb material there is the hazard formed by the transuranic elements. For example, the irradiation of uranium^{238} with low Mev. neutrons forms neptunium 239, a 2.3-day radioelement which W. J. Heiman[7] estimates might constitute 50 percent of the residual activity a few days after a bomb detonation. The growth of Np^{239} in fallout is such that at 1 hour its activity would account for 0.5 percent of the total gamma rays; at 1 day this would rise to 23 percent, reaching a maximum of 50 percent at 4 days. Thereafter it would fall to 40 percent at 1 week, to 12 percent at 2 weeks and to less than 1 percent by 1 month. The radiation due to neptunium is by no means insignificant although it does turn out to be less than the dosage from fission products. This will become clear when we examine the rate of decay of the fission products.

At higher neutron energies, such as certain types of thermonuclear weapons produce, natural uranium undergoes an (n,2n) reaction which competes with fast fission in U^{238}. The data of R. J. Howerton[8] show that U^{238} has a fission cross section of 0.6 barn from 2 to 6 Mev., thereafter climbing to a plateau value of 1 barn for neutrons up to 14 Mev. At 6.6 Mev. there is a threshold for the (n,2n) reaction and the reaction has a cross section of 1.4 barns in the range of 10 Mev. The ready identification of U^{237} in fallout points to fast fission of U^{238} as a main energy source in high-yield megaton-class weapons.

Nuclear weapons necessarily contain significant amounts of elements (stainless steel, for example) which may add to the bomb's radioactivity. This induced activity is probably small although certain long-lived emitters such as cobalt 60 may be produced in significant amounts if small amounts of nickel and cobalt are present. P. O. Strom[9] and his associates have observed the presence of cobalt isotopes in local fallout from the Redwing series of tests in 1956. Presumably this radiocobalt originated in the bomb environment. The amounts of cobalt in ocean water are too small to account for the observed activity. It is interesting to note that the locally deposited cobalt 60 contributed largely to the 1- to 10-year activity in the Redwing sample.

Weapons burst close to the ground will produce a variety of induced activities. The hazard will depend upon the weapon yield, the neutron spectrum, the chemical composition of the substratum, and the depth of the burst. A harbor burst, for example, would induce the 14.8-hour sodium-24 activity which involves very energetic gamma radiation. There is a considerable range of induced activities possible, but it is futile to attempt any specific calculations since they would de-

---

[6] See E. A. Martell, "Atmospheric Circulation and Deposition of Strontium 90 Debris," Air Force Cambridge Research Center paper (July 1958). See also W. F. Libby, "Radioactive Fallout," speech of Mar. 13, 1959.

[7] Variation of Gamma Radiation Rates for Different Elements Following an Underwater Nuclear Detonation," J. Colloid. Science, 13 (1958), p. 329.

[8] "Reaction Cross Sections of U^{238} in the Low Mev. Range," UCRL 5323 (Aug. 15, 1958).

[9] "Long-Lived Cobalt Isotopes Observed in Fallout," Science, 128 (Aug. 22, 1958), p. 417.

pend so strongly upon the factors enumerated above. In general it would be expected that they would add significantly to the fission product radioactivity but would not exceed it in radiation dosage.

Comparison of the role of fission product versus induced activity naturally depends upon the percentage contribution of fission to the total yield of the bomb. The foregoing has assumed a thermonuclear weapon in which the ratio of fission to fusion is 2:1. Weapons with a ratio of 1:10 may be thought of as relatively "clean" but this is subject to qualification, depending upon the operational conditions under which the bomb is burst. Even a 100 percent intestinally clean weapon (as defined by a test in empty space) becomes significantly dirty if the material close to the bomb is irradiated with the bomb's neutrons. This shows the fallacy of the clean bomb concept because for many military applications the detonation has to be so close to the ground that the neutron-induced activities will pose a real hazard to friend and foe alike.

THE FALLOFF OF FALLOUT

Assuming that our estimate of 7,000 roentgens per hour represents the intensity of the fission products 1 hour after detonation, let us project the dose rate into the future. Naturally at the short-lived emitters die out the activity of the fission products will fall off rapidly. This exponential decay follows a $T^{-1.2}$ law first pointed [10] out by K. Way and E. P. Wigner. If one examines the average number of photons per disintegration, it drops from a value of 1.2 at 1 hour to below 1.0 at 10 hours, rises to 1.1 at 100 hours and thereafter decreases to 0.2 at 10 years. The average photon energy for U^{235} fission products drops from 0.92 at 1 hour to 0.7 at 12 hours thereafter decreasing to 0.5 at 100 hours; it climbs to 0.6 for 9-month-old fission products, dips to 0.36 at 2 years, and levels off at 0.6 Mev. at 10 years. These fluctuations reflect the varying isotopic composition of the fission products as a function of time.

[10] "The Rate of Decay of Fission Products," Phys. Review, 73 (1948), p. 1318.

UNFRACTIONATED FISSION PRODUCTS!

NO NEUTRON INDUCED NP239, U237, ETC.

Core samples[19] taken on Gejen Island in 1955 showed the following beta activity:

Soil layer	1st	2d	3d	4th	5th	6th inch
Activity	37,000	37,000	8,000	4,000	4,400	3,400 betas/min/gm

Data taken from soil on other islands indicate a similar soak-in of fission debris down to a depth of 6 to 8 inches. The 1956 resurvey of Gejen soil (table 18 in the reference 18) shows that the residual activity concentrates in the upper inch of soil. Although the data on soil uptake of fission debris are not firm, it appears that, at least in the case of Marshall Island soil, weathering is not severely cumulative in effect. If we compare curves B and C without making allowance for terrain effects, then up to 2 years there is a difference of a factor of about four. A British estimate[20] assumes a "protection factor of three" for British soil contaminated with stratospheric fallout.

Weathering effects beyond 2 years will depend very critically upon the nature of the radioelements which then predominate in the fallout debris. And as we have seen, this is likely to be quite variable. For a normal mixture of fission products, the long-term radiation dosage would depend upon the weathering of cesium in the soil. Cesium should be quickly fixed[21] in the upper soil surface, probably in the first inch. Fixation is assumed to be proportional to the colloidal content of the soil and would be greatest in clay soils and least in sandy loams. Radiocesium would be expected to resist leaching even under conditions of heavy (tropical) rainfall.

THE GAMMA HAZARD

The foregoing discussion makes it appear reasonable to use curve C in estimating the radiation dosage to which people might be exposed from a representative fallout field corresponding to a 1-hour level of 4,000 roentgens per hour. We make use of a $t^{-1.3}$ relation up to 3 weeks and a $t^{-1.5}$ up to 3 months, Previous articles in the Bulletin have already spelled out the nature of the fallout radiation dosages during the first day, so these data will not be repeated. Beginning with the second day table I lists the gamma doses for various time intervals.

Table I

Time interval:	*Gamma dose, roentgens*	Time interval—Continued	*Gamma dose, roentgens*
2d day	950	2d month	220
3d day	500	3d month	100
4th day	300	4th month	60
5th day	225	5th month	40
6th day	175	6th month	25
7th day	120	6th to 12th month	60
2d week	535	2d year	20
3d week	285	3d year	6
4th week	140	4th year	3

Use of the $t^{-1.2}$ law involves a great overestimate of the actual radiation hazard over long periods of time. For example, the 1 to 4 years dose is 27 times higher than that represented by curve C. Since the dose beyond 4 years is very cesium-sensitive, any estimate must depend upon assumptions about the degree of fractionation of Cs^{137} in the fallout and degree of weathering. If one assumes no fractionation and a uniform deposit over a hard, flat plane then the level corresponding to 400 curies of Cs^{137} per square miles would produce a dose of 380 roentgens over a period of 50 years. No experimental data

[19] From table 15 of AEC publication, "Radioactive Contamination of Certain Areas in the Pacific Ocean From Nuclear Tests," Editor G. Dunning (August 1957).

[20] N. G. Stewart, R. N. Crooks, and E. M. R. Fisher, "The Radiological Dose to Persons in the United Kingdom Due to Debris From Nuclear Test Explosions Prior to January 1956," AERE HP/R 2017 (1957).

[21] W. Langham and E. C. Anderson, "Entry of Radioactive Fallout Into the Biosphere and Man," Bull. Swiss Acad. Med. Sci. 14 (1958), p. 434.

F. P. Cowan[12] has investigated the buildup of fallout on construction materials and he has found that smooth-surfaced materials such as aluminum accumulate the least fallout and yield most quickly to decontamination, whereas asphalt and asbestos shingles hold the fallout more tenaciously.

After 1 week a properly indoctrinated householder might attempt to reduce the contamination on the roof. A twentyfold reduction of the roof contamination (as compared with open field levels) seems feasible. Since the roof contamination contributes as much radiation dose to the basement as the skyshine of radiation from adjoining land[13] an overall tenfold dose reduction for basement dwellers is possible.

Decontamination of ground areas and pavements will involve an organized effort and substantial equipment. The U.S. Navy has had practical experience in radiological decontamination as a result of the Bikini bomb tests in 1946. Data[14] from the U.S. Naval Radiological Defense Laboratory show that firehosing of asphalt surfaces contaminated with dry fallout can reduce the level of radioactivity thirtyfold.

In the absence of extensive decontamination it would appear wise to live very cautiously during the 1-week to 1-month period after attack. The second week dose of about 500 roentgens should be kept below 20 roentgens and preferably below 10 roentgens. The same rule applies to the third week. The 140 roentgen dose which would be accumulated by full above ground exposure during the fourth week can be cut to 7 roentgens by an overall reduction factor of 20; this still requires basement living unless decontamination has been effective.

BEYOND 1 MONTH

Once the challenge of the first month of postattack living has been met, the radiation hazards in the following months can be put into manageable proportions by cautious living. At about the time the outdoor levels will be about 10 roentgens per day—still too high for long-term above-ground movement. However, local decontamination and restricted movement plus indoor living as much as possible should make it possible to keep the radiation dose below 10 roentgens for the second month. Thereafter the radiation exposures call for caution but the problem is clearly no longer an acute one.

After 4 months the maximum 24-hour dose for a man in the open would be about 1 roentgens although it might be 10 times less in a decontaminated area. At the end of 1 year an untouched area should exhibit about 0.1 roentgens per day and the total dose in the second year after attack would be about 20 roentgens so that return to ordinary life as far as the external hazard is concerned would be indicated. For people who had accumulated 100 roentgens in the first year an additional 5 roentgens in the second year (allowing for shielding) would not constitute undue risk. Since the impact of the attack might replace our industrial economy with a colonial type of existence millions of people would have to till the soil, this would involve greater exposure but it would not be prohibitive.

These conclusions apply to the radiation field specified by a fallout of 2 kilotons of fission products per square mile. It would seem that this kind of a fallout field is a reasonable projection through the early sixties.

---

[12] "The Accumulation of Radioactive Fallout on Typical Materials of Construction," BNL–497 (March 1958).

[13] J. A. Auxier et al., "Experimental Evaluation of the Radiation Protection Afforded by Residential Structures Against Distributed Sources," CEX–58.1 (Jan. 19, 1959). See also M. J. Berger and J. C. Lamkin, "Simple Calculations of Gamma-Ray Penetration Into Shelters: Contribution of Skyshine and Roof Contamination," Report NBS–2827 (February 1958).

[14] "Radiological Recovery of Fixed Military Installations," USNRDL report dated August 1953.

STATEMENTS OF WILLIAM T. HAM, JR.,[1] DEPARTMENT OF BIOPHYSICS, MEDICAL COLLEGE OF VIRGINIA; GEORGE MIXTER, JR.,[2] ASSOCIATE PROFESSOR OF SURGERY, NEW YORK UNIVERSITY POSTGRADUATE SCHOOL OF MEDICINE; AND COMDR. CHARLES H. FUGITT,[3] U.S. NAVY, RADIATION CONSULTANT

Representative HOLIFIELD. We are glad to have you three gentlemen here, and Dr. Ham, will you please take the lead in the presentation.

Dr. HAM. Mr. Holifield and members of the committee, I feel it a very responsible position in which I am placed in trying to present to you gentlemen the thermal effects of radiation from 1- to 10-megaton weapons. In a certain sense, in the discussion so far, I cannot help but feel that the cart has been put before the horse in the sense that we have got to survive first before we can be subjected to the effects of fallout.

I should like to ask the indulgence of the committee in being able to refer to my two colleagues on questions if they come up during the testimony which might be more appropriately answered by them than by me.

Representative HOLIFIELD. This is in order.

Dr. HAM. Thank you, sir. With that I will read my text or testimony, and if there are questions I will do my best to answer them.

THERMAL INJURY FROM NUCLEAR WEAPONS

The use of fire as a weapon in warfare has been traditional since the earliest historical times. Burn injury is painfully familiar to all of us. However, the advent of nuclear weapons in modern warfare has introduced thermal injury on a scale outside our previous experience. The sudden production of severe burns on a mass casualty basis pre-

---

[1] Dr. Ham was educated at the University of Virginia, receiving the doctor of philosophy degree in physics. He has been on the faculty of Columbia University and the University of Virginia, where he also worked on special investigations for the OSRD and Manhattan project. He served in the U.S. Marine Corps in the Pacific during World War II as a radar officer and has been professor and chairman of the Department of Biophysics and Biometry at the Medical College of Virginia since 1953. Dr. Ham is a fellow of the American Physical Society and several other scientific societies. He is a consultant of the Atomic Bomb Casualty Committee of the National Academy of Sciences—National Research Council, the Oak Ridge National Laboratory, and the Army Medical Service Graduate School. He is the author of numerous articles on radiobiology and thermal injury, and has participated in nuclear weapons tests.

[2] Dr. Mixter was educated at Harvard College and Harvard Medical School, receiving the degree of doctor of medicine, and has been certified by the American Board of Surgery. He served with the U.S. Marines in the Pacific during World War II as a medical officer. He has been a research fellow in surgery at the Boston University School of Medicine and chief resident in surgery at Massachusetts Memorial Hospital. He has also held other research fellowships in medical and surgical research at Western Reserve University and Cleveland City Hospital. Dr. Mixter has been on the faculty of the University of Rochester School of Medicine, and was the responsible investigator on a series of flash burn studies for the Atomic Energy Commission. He is currently associate professor of surgery at New York University Post-Graduate Medical School and visiting surgeon at Bellevue Hospital, and attending surgeon at University Hospital and Manhattan Veterans Hospital. He is also consultant in biomedicine to the Navy Materials Laboratory, and has published many papers on surgery and thermal injury.

[3] Commander Fugitt was educated at the George Washington University, the Massachusetts Institute of Technology, and the University of California at Berkeley, receiving the doctor of philosophy degree from the latter institution in biophysics. He has been a teaching fellow and a member of the Laboratory for Nuclear Science at the Massachusetts Institute of Technology, and Chief of the Biophysics Division of the Aviation Medical Acceleration Laboratory at the Naval Air Development Center. He has also participated in nuclear weapons tests in the Pacific and in Nevada. Concurrent with his present military assignment to the Defense Atomic Support Agency, he has been a professional lecturer in the School of Medicine of the George Washington University. Commander Fugitt has published papers on the thermodynamic and spectral properties of biological materials.

Senator HICKENLOOPER. I was wondering if there might be a vacuum effect which would have a substantial effect on body tissues and life itself. If there is a sudden vacuum created as a result of this explosion, that is what I have in mind.

Dr. HAM. I don't know, sir. I think this is something that involves the blast effect which Dr. White is going to testify to and I prefer to leave that to him. I am here in the unfortunate role of being an apostle of fire and I think I had better stick to that, sir.

Representative HOLIFIELD. You may proceed.

Dr. HAM. When one compares this factor with the lethal fallout area resulting from the same surface detonation, one is immediately impressed by the fact that fire, in many cases, will impose a much greater hazard to many more people and buildings than the fallout. If one envisions a city complex of appproximately 25 miles in radius, in which the enemy is successful in detonating a 10-megaton surface burst near its center, then the entire complex will be at risk from fire, while only about 20 or 25 percent will be inside the lethal fallout area, most of which will be disposed downwind outside the highly populated area. The complete blast destruction zone is considerably smaller than either of the other two areas, being a circle about 7 miles in radius, or about 150 square miles.

Actually that area which Dr. Mixter has outlined is about one-sixth of the total area of 2,000 square miles encompassed by the outside red circle.

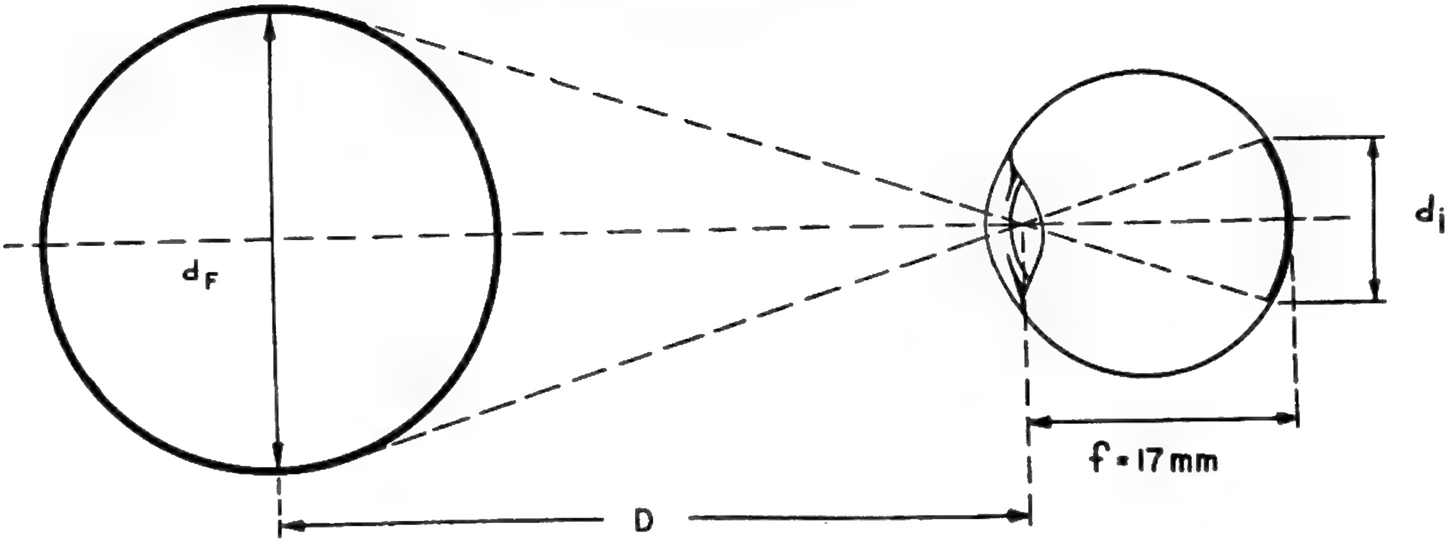
It is believed that fire storms are an almost inevitable consequence of a megaton drop on a large American city. Just what measures can be adopted for survival during a fire storm are not readily apparent. Survivors of the initial effects of blast, thermal and ionizing radiation from a megaton burst must cope also with the incinerating heat of fire storms. Severe burn casualties from secondary fires will outnumber vastly flash burn casualties from the fireball.

Thermal injury to the eye: The hazards of flash blindness and retinal burns from nuclear explosions have received increasing attention during the past few years because of the extremely long distances over which these phenomena have been produced. Neither flash blindness nor retinal damage constitute major hazards during the daytime because of the restricted pupillary diameter which limits the amount of light entering the eye; furthermore, the blink reflex, 100–150 milliseconds, protects the eye from undue amounts of radiation, except in those cases where the thermal pulse is delivered within extremely short times. This is the case for low-yield weapons on the ground and for weapons of any yield exploded at very high altitudes. Under the conditions stipulated in this investigation, the hazards of flash blindness and retinal damage would be negligible.

Representative HOLIFIELD. On that point, let me ask you, what happened in the case of the eyes of the animals that were exposed to the Johnston Island test? Can you testify on that?

Dr. HAM. Sir, with your permission I would like to defer that until we have completed the paper and then Col. John Pickering is in the audience here and has some slides and, if you would permit me, I would very much like to call Colonel Pickering to give some testimony

FIGURE IV



$$d_i = d_F \frac{17}{D}$$

Representative HOLIFIELD. You have used the term "greatly exceed." Do you have any experimental knowledge which enables you to put that into specific focus?

Dr. HAM. I do have some, sir. I think Colonel Pickering will speak about this again, too.

Representative HOLIFIELD. That is fine.

Dr. HAM. If we could defer that, I would prefer it.

Representative HOLIFIELD. Go right ahead.

Dr. HAM. Retinal burns from viewing the sun during an eclipse are well known to ophthalmologists. The fireball of a nuclear weapon is many times brighter than the sun and will produce severe retinal damage if viewed deliberately.

BURN TREATMENT

Nuclear warfare on the scale being discussed here would produce severe burn casualties out of all proportion to any previous medical experience.

Figure V illustrates the mortality to be expected from burns as a function of burn area and age of patient. These mortality figures apply only to people who receive optimum care in a hospital burn clinic where complete resources of medical science are devoted to the burn patient.

DR HAM:

high-yield nuclear detonation. Rabbits were placed at distances up to 300 nautical miles from the point of detonation in order to obtain the necessary data.

The biomedical project showed that a very high altitude nuclear explosion can be particularly damaging to the eye because of the rapid rate at which the power pulse delivers thermal energy and the relatively low atmosphere attenuation encountered. A high-altitude detonation in the megaton yield range, such as Teak, delivers a great percentage of its thermal energy during a small fraction of a second after the detonation. Consequently, with a blink-reflex time of just over a quarter of a second for the rabbit and less than a quarter of a second for man, nearly all of the radiant exposure from a very high-altitude burst is received by the retina before the eye can be protected by blinking if the person is looking directly at the burst at the time of detonation. This is in contrast to low altitude detonations of the same size, where the power pulse is much slower in overall delivery of its thermal component and where the blink reflex can provide a measure of protection.

TEAK, 3.8 Mt @ 77 km!

Small retinal burns were produced in the rabbits at distances up to 300 nautical miles. Burn diameters consistently correlated with distance from the burst, with progressively smaller lesions being encountered at increased distances. For example, the burn lesions were approximately 2 millimeters in diameter at about 40 miles distance, decreasing to 0.5 millimeter at 300 miles. Corresponding lesions of smaller diameter might be expected at larger distances provided the burst height were great enough to allow a direct view of the fireball over the edge of the horizon. Curvature of the earth will cause the position of the fireball to be below the horizon, and therefore incapable of inflicting retinal damage.

In order to preclude damage to the sooty tern, a large bird indigenous to the Johnston Islands, special precautions were taken during the Orange shot. A water spray simulated rain and kept the birds grounded. Smoke together with local clouds further attenuated thermal effects.

No precautions were necessary for the Teak shot due to its higher altitude. The protective measures for the Orange shot were successful.

SUMMARY OF TEST OBJECTIVES AND RESULTS REGARDING FLASH BLINDNESS AND RETINAL BURNS

The effect of nuclear detonations on human eyes was recognized early in the testing procedures when the Aviation School of Medicine of the U.S. Air Force performed Project 4.3, "Flash Blindness," in Operation Buster. The objective of this project was to evaluate the visual handicap which might be expected in military personnel exposed, during daylight operations, to the flash of an atomic detonation and to evaluate devices developed for the purpose of protecting the eyes against visual impairment resulting from excessive exposure to light. The data obtained on this test, as revealed in the test report, showed that no serious handicap is encountered during exposure to atomic detonation during daylight operations at the distance from the detonation which would be safe from the standpoint of other hazards. This conclusion was subsequently disproved by the recent Hardtack test series in the Pacific, using rabbits as specimens.

In the Tumbler-Snapper test series retinal burns were not investigated, with the Air Force School of Aviation Medicine this time investigating flash blindness. However, on this series some work was done on atmospheric transmissivity, which has proved subsequently to be of some help in the problem of retinal burn prediction.

In Operation Upshot-Knothole, research was conducted to determine to what degree the flash of an atomic detonation impairs the vision and reduces the efficiency of military personnel during nighttime operations. This is a serious problem because the individual has pupils which are more or less widely dilated, depending upon the amount of light to which the eye is being exposed prior to detonation. The conclusion was that a significant loss of central peripheral vision occurs temporarily following exposure to an atomic detonation. It was also concluded that the types of filters tested served to shorten by about 30 percent the normally long period of incapacitation in unprotected individuals as measured in the previous Tumbler-Snapper operations.

The objective of the retinal burns portion of this test was to find the extent of damage caused by exposure of the dark-adapted rabbit eye to the high intensity illumination of an atomic detonation, with appropriate evaluation to determine whether human eyes might suffer similar injuries under the same

Dr. MIXTER. The exact number is presumably incalculable. In any case the number is mentioned only as an indication of the complete hopelessness of the problem confronting the medical profession.

(The following was subsequently handed to the chairman of the subcommittee:)

DEAR MR. HOLIFIELD: There are 226,625 physicians in the United States, of which 16,598 are in Government service, that is, Army, Navy, Air Force, Public Health Service, Veterans' Administration, and Indian Service. Figures are for the year 1958.

FRANK BARTON,
Secretary of the Council on National Defense,
American Medical Association.

Representative HOLIFIELD. Proceed, Dr. Ham.

Dr. HAM. Yes, sir. It is obvious that under such conditions it would be impossible to give burns or any other casualties such treatment as is now known to result in minimal mortality. The surviving doctors' primary responsibility must be to select those casualties reasonably capable of ultimate survival, and to concentrate every effort upon their survival. This means that under conditions of inadequate supplies of opiates, dressings, and sterile fluids, the vast majority of casualties will receive only token treatment. It is not the province of the present discussion to define accurately either the number of casualties or how they will be treated, but it must be unequivocally stated that, under the conditions predicated for this investigation, only a small percentage of the injured population could, or indeed should receive even an approximation to adequate medical treatment.

Burn victims might be sorted into three groups according to percentage burn area, 25 percent or less, 25 to 50 percent, and greater than 50 percent. Those having burns covering 50 percent of the body area or more would be given opiates for pain and neglected; the group having 25 to 50 percent area burns would be treated with all available resources in the field; the 25 percent or less groups would be given oral electrolyte treatment, opiates for pain, and dismissed.

Representative HOLIFIELD. Would you please tell me what oral electrolyte treatment is?

Dr. HAM. Dr. Mixter will.

Dr. MIXTER. This very simply means salt water mixed in a proportion which will not make the person ill but will supply them with the salt, and if you have the soda bicarb, which is the ideal fluid, to allow their life to be prolonged. Extensively burned people are not capable of eating any solid food. They won't accept it. Various emergency fluids have been worked out. This information should be a part of the information of any one concerned with any type of disaster work. It should be known because the fluids used for intravenous use will be in short supply, indeed if there are any. Even pure water suitable for drinking will be in short supply. Oral electrolyte is salt water.

Representative HOLIFIELD. That is very plain. Even I understand that.

Dr. HAM. Burns involving more than 25 percent of the total body area represent severe traumatic cases demanding at least five details of emergency treatment: (1) relief of pain; (2) emergency dressing, if possible; (3) prevention and treatment of burn shock; (4) salt and

water requirements to insure adequate urinary output; (5) the most feasible antibiotic therapy to aid in combating infection. Of all the types of traumatic injury following a nuclear attack, severe burns make perhaps the greatest demands upon medical personnel and resources. Successful treatment requires stockpiles of plasma, whole blood, plasma substitutes, antibiotics, emergency dressings, narcotics, et cetera. The treatment period is long and arduous. Burn wounds greater than first degree always become infected and prolong the treatment phase. Exposure to ionizing radiation complicates the picture because the body's defenses against infection and bleeding have been impaired. Combined injury from thermal and ionizing radiation presents grave problems in therapy. ⇒ DUCK AND COVER.

The conclusion seems inevitable that millions of severe burn casualties would overwhelm our capacity for adequate medical treatment. Mortality figures for burn victims would be extremely high. It is no exaggeration to say that, after nuclear attack, burn casualties represent the most serious immediate medical problems facing the Nation.

Representative HOLIFIELD. Thank you very much, Dr. Ham.

Are there any questions of the witness?

Representative WESTLAND. Mr. Chairman.

Representative HOLIFIELD. Mr. Westland.

Representative WESTLAND. The nations have been using fire as a weapon for hundreds of years, all the way from the Indians using bow and arrows with fire on them to set the house on fire, up to recent wars with flamethrowers, napalm bombs, and so forth. Isn't what you are really saying here is that man has now created a weapon with which he can destroy his fellow man in greater quantities and with greater efficiency? Is that not just about the size of it?

Dr. HAM. Yes, sir; I think that is, with very great efficiency, especially in terms of magnitude of something that we have never had previous experience in. In modern warfare in the past there have been filled hospitals and bad burns have been able to be treated because they came in in small numbers. But you are here faced with the instant production, so to speak, of perhaps millions of burns casualties, and the question is what can we do about it. The answer we are trying to drive across is that the ordinary treatments that we do adopt under the best conditions for burns would be absent and that the mortaility figures for burns would be much greater under such conditions. It is our estimate and feeling that burns would produce a tremendous amount of mortality in the country under nuclear attack.

Representative WESTLAND. You are saying that the medical protection would simply be unable to cope with such a situation.

Dr. HAM. Exactly, sir.

Representative WESTLAND. I would assume that this same information which you have presented here so well this afternoon is available to other nations, too, who possess this lethal weapon.

Dr. HAM. Yes, sir; I think that is correct.

Representative BATES. Doctor, could not a lot of these things which you have suggested here be done by first aid treatment by people who have had a little experience in this field?

Dr. HAM. Yes, I think that is very true. I think Dr. Mixter would prefer to speak to you about that, Mr. Bates.

STATEMENT OF DR. CLAYTON S. WHITE,[1] DIRECTOR OF RESEARCH, LOVELACE FOUNDATION FOR MEDICAL EDUCATION AND RESEARCH, ALBUQUERQUE, N. MEX.

Dr. WHITE. Thank you, Mr. Holifield, members of the committee and ladies and gentlemen. Initially I wish to make a few preliminary remarks. First, it is a pleasure to express my appreciation to the committee and to the staff for making it possible for me to appear today, which is later than the original schedule. This was very helpful. Secondly, I want to acknowledge the aid of Mr. I. G. Bowen, who is head of the physics department of the Lovelace Foundation in Albuquerque, whose knowledge and computational skill contributed to the analytical work that was incorporated in the prepared statement.

Thirdly, the work in blast biology with which I have been associated since 1952 has been sponsored mostly but not entirely by the Atomic Energy Commission under contract with the Division of Biology and Medicine.

Fourthly, I welcome the opportunity to talk about biological blast effects which certainly comprise one of the major early weapon effects responsible for hazard to man.

Fifthly, with regard to formalities, you have already mentioned the biography that was available for the record and I have furnished a prepared statement and wish to say that that is also for the record, if this is your pleasure.

Representative HOLIFIELD. It will be accepted in its entirety for the record.

(The statement referred to follows:)

---

[1] Born, 1912, Fort Collins, Colo. A.B., University of Colorado, 1934 (State scholarship); instructor, psychology, University of Colorado, 1934–35; B.A., University of Oxford, England, 1935-38 (Rhodes scholar): instructor, physiology, University of Colorado School of Medicine, 1938–40 and 1941–42; member of faculty, Department of Physiology and Pharmacology, University of Colorado School of Medicine, 1940-41: M.D., University of Colorado School of Medicine, 1942. Internship, University of Colorado School of Medicine and Hospitals, Colorado General Hospital, Denver, 1942–43; course in aviation medicine, U.S. Naval School of Aviation Medicine, Pensacola, Fla., with flight training, and designation as flight surgeon in January 1944. Medical officer and flight surgeon, Medical Corps, U.S. Navy, July 1943 to August 1947. Staff, Lovelace Clinic, Albuquerque, N. Mex., 1947–50. Director of Research, Lovelace Foundation for Medical Education and Research, Albuquerque, 1950 to present. Project officer, AEC project, Lovelace Foundation, dealing with the biological effects of blast from bombs, 1952 to present. Participated in 1953, 1955, and 1957, Nevada test series, under the administrative direction of Mr. R. L. Corsbie, director, civil effects test group. Director, program 33 (blast biology), CETG, Nevada test operations, 1955 and 1957. Chairman, AEC Ad Hoc Committee on Blast Biology, 1958 to present. Consultant, Douglas Aircraft Co.; Consolidated Vultee Aircraft Corp. Chairman, Aeromedical and Biosciences Panel of the U.S. Air Force Scientific Advisory Board. Fellow: American Association for the Advancement of Science; Aero Medical Association. Member: Phi Beta Kappa, Alpha Omega Alpha; Sigma Xi; Nu Sigma Nu; Society for Experimental Biology and Medicine: New Mexico State Medical Society; New Mexico Society for Biological and Medical Research; Bernalillo County Medical Society; Bernalillo County Heart Association; American Medical Assoiation; American Board of Preventive Medicine, specializing in aviation medicine; Space Medicine Association of the Aero Medical Association. Present: Director of Research, Lovelace Foundation.

Figure 2. Missile and other blast damage to liquid storage tanks located about 3200 ft from one of the Texas City explosions. After Armistead (81).

16 April 1947.

Texas City: hot metal shrapnel from exploding ships starts fires

Table 5

The Velocity-Mass-Probability Relationships Required for Small Window Glass Fragments to Traverse the Abdominal Wall and Reach the Peritoneal Cavity of Dogs*

Mass of glass fragment gms	Impact velocities in ft/sec for indicated probabilities of penetration in per cent		
	1%	50%	99%
0.05	320	570	1000
0.1	235	410	730
0.5	160	275	485
1.0	140	245	430
10.0	115	180	335

*Data from Bowen, et al., AECU-3350

The reader will note that a 10 gm glass fragment, having a velocity of 115 ft/sec has only a 1 per cent probability of traversing the abdominal wall of a dog. Since clothing will degrade the velocity of small missiles moving relatively slowly, and because of the less serious nature of skin and tissue lacerations, an impact velocity of 115 ft/sec for a 10 gm glass fragment has been arbitrarily chosen as the threshold for human casualties from glass and other frangible materials. Such a decision may well have to be modified later, since a quantitative study of eye injury from glass and other small irregular missiles has not yet been done. However, the 10 gm-115 ft/sec criteria is strengthened somewhat by the data of Journee (5) who noted that spherical bullets weighing 8.5 gm only produced a contusion of the skin when fired at human cadavers at velocities up to 150 ft/sec, whereas a velocity of 128 ft/sec for 6 to 12 mm caliber rifle bullets was set as the lower limit at which penetrating wounds begin in man (5).

The realistic nature of the masses and velocities of glass fragments noted in Table 5 is established by the figures in Table 6 which details the masses and velocities for glass, stone and irregular steel objects empirically observed at stations located from the 1.9 to 17.3 psi lines during full-scale nuclear explosions at the Nevada Test Site. Unfortunately, to date, no full-scale missile experiments have been carried out to determine the expected missile environment inside a variety of industrial plants, office buildings

Table 6

Relation Between Overpressure and Missile Parameters

Max pressure psi	Type of missile	Velocity ft/sec geometric mean	Velocity ft/sec range	Mass, gms geometric mean	Mass, gms range	Max missile density No/sq ft
1.9	Window glass	108	50-178	1.45	0.03-10	0.4
3.8	Window glass	168	60-310	0.58	0.01-10	159
5.0	Window glass	170	50-400	0.13	0.002-140	388
8.5	Natural stones	275	167-413	0.23	0.038-22.2	35
15.0	Natural stones	692	379-1100	0.50	0.043-8.82	4.7
17.3	Natural stones	432	300-843	0.21	0.010-13.4	99.1
17.3	Irregular steel objects	240	195-301	34.5	9.0 - 86.0	3.6

43338 O—59——22

and other structures much larger than the "typical" brick and wooden frame houses to which past studies have been limited.

Objects striking the human head may cause skull fracture and concussion, both potentially dangerous experiences. Fortunately, quantitative investigations by Gurdjian, et al. (70), using human material, are available to support an estimate of the skull-fracture hazard. Using the data of these authors and adopting a missile of 10 lbs, which is near the average weight of the adult, human head, Table 7 was computed to state the impact velocities that can be associated with skull fracture. The table shows considerable variation in velocities required for fracture; e.g., the minimum impact velocity associated with fracture was near 15 ft/sec, while the maximal without fracture was computed to be 23.1 ft/sec.

Table 7

Average Minimal Impact Velocities From a 10 lb. Missile Expected to Cause Skull Fracture and Maximal Velocity Without Fracture

Region of blow	Impact velocities expected to fracture the human skull*	
	ft/sec	mph
Posterior midline	16.6	11.3
Frontal midline	17.4	11.8
Above ear	18.2	12.4
Top midline	19.4	13.2
Maximal without fracture	23.1	15.7
Minimal with fracture	14.6	9.9

*Computed from the data of Gurdjian, et al. (70)

Although damage to the thorax and lungs from the impact of 0.4 and 0.8 lb. nonpenetrating missiles have been studied, information for heavier and lighter objects is lacking (64, 82). Also unavailable, are quantitative figures for missile impact velocities near and over the regions of the liver and spleen that will rupture these friable organs and produce hemorrhage often severe enough to require early surgery if fatality is to be avoided.

Under such circumstances, 10 ft/sec has been adopted tentatively as the impact velocity for a 10 lb nonpenetrating missile, below which the number of human injuries will approach a minimum.

Tertiary Effects

To deal simply with the hazards of displacement from blast-produced winds, it has been assumed that significant human injury will occur mostly during decelerative impact with solid objects having a mass much greater than that of man. Data from four sources has been selected as guides in estimating threshold conditions for injury.

First, it is useful to note an animal study involving decelerative impact which reported the impact velocities associated with 50 per cent mortality in mice, rats, guinea pigs, and rabbits to be 38, 44, 31 and 31 ft/sec, respectively. Extrapolation of these figures to man predicts that on the average an impact velocity of 27 ft/sec or 18 mph would be associated with death of half the individuals (82). These are interesting figures because National Safety Council reports on urban automobile accidents have associated a mortality of 40 per cent with automobile accidents at speeds of less than 20 mph and a 70 per cent fatality rate with speeds of less than 30 mph (69). Table 8 summarizes the above data.

Secondly, Black, et al. (76) dropped human cadavers feet first with knees locked onto a hard surface from heights of 1, 2, 3, 4 and 6 feet and concluded that the threshold for fracture of the heel, foot and ankle bones lay between impact velocities of 11 and 16 ft/sec. Draeger, et al. (79) using an impact table and human cadavers to study ankle and foot fracture, demonstrated an impact velocity of 12-13 ft/sec (8-9 mph) to be near the threshold for skeletal fracture of the lower extremities.

Thirdly, Gurdjian, et al. (70), by drops onto a solid surface, subjected heads of human cadavers to impact loading and defined conditions for experimental skull fracture. The findings have been summarized in Table 9 in terms of impact velocity. Fracture was produced at a minimal impact velocity of 13.5 ft/sec (9.2 mph), while the maximal velocity without occurrence of fracture was 22.8 ft/sec (15.5 mph). These findings are fairly consistent with British work done during the Second World War (76, 78).

Table 8

Average Velocities of Impact Against a Hard Surface Associated with 50 Per Cent Mortality of the Indicated Species of Animals with Extrapolation to Man*

Species of Animal	Average animal mass gms	Average impact velocity for 50 per cent mortality ft/sec	mph	Equivalent height of fall (approx.) ft
Mouse	19	38	26	22
Rat	180	44	30	30
Guinea pig	650	31	21	15
Rabbit	2,600	31	21	15
Man (computed)	72,574 (160 lbs)	27	18	11

National Safety Council release on urban automobile accidents shows 40 and 70 per cent of fatalities were associated respectively with speeds of or less than 20 and 30 mph. - Quoted from De Haven.

*Data AEC Project, Lovelace Foundation, Albuquerque, N.M.

Table 9

The Ranges of Impact Velocities Associated with Experimental Fracture of the Human Skull

Range impact velocities ft/sec	Approx. velocity in mph	Approx. height of fall in.	Number of subjects	Fractures in per cent
13.5-14.9	9.5	37	9	19
15-16.9	10.9	48	10	22
17-18.9	12.2	61	12	26
19-20.9	13.6	75	11	24
21-22.9	15.0	91	4	9
Total			46	100

Minimum velocity with fracture - 13.5 ft/sec (9.2 mph)
Maximum velocity with fracture - 22.8 ft/sec (15.5 mph)
Maximum velocity without fracture - unstated.

Fourthly, from the findings of Ruff (84), it is possible to deduce a velocity of about 8 ft/sec (6 mph) as likely to produce spinal fracture assuming impact with a solid surface in the sitting position.

The above data encourages one to adopt an impact velocity of 10 ft/sec as a tentative threshold criteria for human damage from abrupt decelerative impact following displacement by blast-produced winds. Though arbitrarily chosen, the 10 ft/sec (6.8 mph) figure is quite likely low enough to avoid any significant number of casualties and if serious injuries occur, they are likely to be few indeed.

Empirical work by Taborelli, et al. (51, 52) in the 1957 Nevada Test Series, using 160 lb anthropometric dummies exposed at stations where measured overpressures were 5.3 and 6.9 psi, demonstrated the displacement possible to humans from nuclear blast. Table 10 summarizes the findings.

Table 10

Blast Displacement of 160 Lb Anthropometric Dummies

Max pressure psi	Max Q psi	Initial dummy position	Max horizontal velocity ft/sec	Time to max velocity sec	Displacement in ft
5.3	1.8	Standing	21.4	0.5	21.9 downwind
“IDEAL”		Prone	zero	-	None
“PRECURSOR” BLAST 6.9	15.4	Standing	not known	not known	256 downwind 44 to right
		Prone	not known	not known	124 downwind 20 to right

Even at 5 psi the maximal velocity attained in 0.5 sec by the dummy was a little over 21.4 ft/sec, which speed is well above those required to fracture the skull and lower extremities. Though the displacement velocity at 6.9 psi was not obtained in the Nevada studies, the total displacement of 124 and 256 ft for the prone and standing dummies, respectively, demonstrates the unequivocal displacement hazard which can occur following nuclear explosions.

Miscellaneous Effects

No attempt has been made to deal with the threshold for human casualties as a consequence of miscellaneous blast effects. Those, however, who wish to explore the dangers from dust are referred to the publication of Desaga (80).

Summary

The tentative criteria described above for primary, secondary, and tertiary blast effects representing those conditions thought to be near the human casualty threshold are summarized in Table 11. It is the current opinion of the writer that the data in Table 11 represent best estimates for conditions at which human casualties will approach a minimum; e.g., some individuals situated where the indicated overpressures, missile and displacement velocities exist will escape damage because of fortunate local geometry; many persons will be injured, but only to the extent that they can care for themselves; others will become casualties in that they require care from their associates, but these will be relatively few indeed.

Table 11

Threshold Criteria Estimated to be Near Conditions at Which Casualties Will Approach a Minimum or be Absent

Blast Effect		Criteria adopted as indicated
Primary	Lung damage	15 psi incident and maximal overpressure 6 psi incident reflecting to 15 psi maximal
	Eardrum rupture	5 psi incident and maximal overpressure 2.5 psi incident reflecting to 5 psi maximal
Secondary	Penetration into abdomen	115 ft/sec for a 10 gm glass missile
	Nonpenetrative skull fracture	10 ft/sec for a 10 lb masonry missile
Tertiary	Skull fracture from impact	10 ft/sec for 160 lb man

Table 16

Comparative Weapons Effect Data
Applicable to Indicated Blast Criteria
for a 1 MT Surface Burst at Sea Level

Incident over-pressure psi	Range in mi	Initial ionizing radiation rem	Thermal radiation cal/cm^2	Blast criteria for primary, secondary and tertiary effects
1.9	5.5	<10	7.2	Displacement of man 160 lb 10 ft/sec in 28 ft
2.1	5.1	<10	8.4	Displacement of man 160 lb 10 ft/sec in 10 ft
2.2	4.9	<10	9.3	Missiles (glass) 10 gm 115 ft/sec in 10 ft
2.2	4.9	<10	9.3	Missiles (masonry) 10 lbs 10 ft/sec in 26 ft
2.4	4.6	<10	10	Missiles (masonry) 10 lbs 10 ft/sec in 10 ft
2.5	4.5	<10	11	Eardrum rupture assuming pressure reflection
4.3	3.1	<10	25	Displacement of man 160 lb 10 ft/sec in 1 ft
5.0	2.8	<10	31	Eardrum rupture, assuming no pressure reflection
6.0	2.6	<10	37	Lung damage assuming pressure reflection
15.0	1.5	500	120	Lung damage assuming no pressure reflection

Computed and prepared by Bowen(86)

ASSUMES STANDING POSTURE;
NO DUCK & COVER!

Table 17

Comparative Weapons Effect Data
Applicable to Indicated Blast Criteria
for a 10 MT Surface Burst at Sea Level

Incident over-pressure psi	Range in mi	Initial ionizing radiation rem	Thermal radiation cal/cm^2	Blast criteria for primary, secondary and tertiary effects
1.3	16	<10	7.2	Displacement of man 160 lb 10 ft/sec in 58 ft
1.5	14	<10	9.5	Missiles (masonry) 10 lb 10 ft/sec in 58 ft
1.8	12	<10	13	Displacement of man 160 lb 10 ft/sec in 10 ft
2.1	11	<10	16	Missiles (masonry) 10 lb 10 ft/sec in 10 ft
2.2	11	<10	16	Missiles (glass) 10 gm 115 ft/sec in 10 ft
2.5	9.7	<10	21	Eardrum rupture assuming pressure reflection
4.3	6.8	<10	46	Displacement of man 160 lb 10 ft/sec in 1 ft
5.0	6.1	<10	58	Eardrum rupture assuming no pressure reflection
6.0	5.5	<10	74	Lung damage assuming pressure reflection
15.0	3.3	10	220	Lung damage assuming no pressure reflection

Computed and prepared by Bowen(86)

ASSUMES STANDING POSTURE:
NO DUCK & COVER!

Lung damage threshold:

incident and maximal pressure of 15 psi and at 6 psi incident overpressure for conditions wherein a reflection to 15 psi max occurs, and (2) rupture of the eardrum beginning at an incident and maximal overpressure of 5 psi and at an incident overpressure of 2.5 psi under circumstances where reflection to 5 psi max will occur.

b. Secondary blast effects for penetrating and nonpenetrating missiles; the former referred to a 10 gm glass missile having a velocity of 115 ft/sec which has a 1 per cent probability of traversing the abdominal wall of a dog and entering the abdominal cavity; the latter was estimated considering a 10 lb masonry missile travelling 10 ft/sec as having only a slight chance of producing significant head and body injury.

c. Tertiary blast effects assumed damage only on decelerative impact, and displacements involving velocities of 10 ft/sec for a 160 lb man were considered low enough to avoid significant numbers of serious head and skeletal injuries.

8. The tentative criteria arbitrarily adopted to "fix" the threshold for blast casualties were related to nuclear weapons of 1 and 10 MT yield, surface detonated at sea level, in terms of overpressures, ranges and areas involved.

9. The maximal ranges at which primary effects would be noted were estimated as follows:

Effect	1 MT	10 MT
Eardrum rupture	4.5 mi	9.7 mi
Lung damage	2.6 mi	5.5 mi

10. The estimated maximal areas involved for primary effects were:

Effect	1 MT	10 MT
Eardrum rupture	64 sq mi	300 sq mi
Lung damage	21 sq mi	95 sq mi

the masonry missile, nonpenetrating, 10 pounds in weight also——

Senator HICKENLOOPER. Would you mind an interruption, Dr. White?

Dr. WHITE. No, sir.

Senator HICKENLOOPER. Just to make clear your table here, do I understand that a 10-gram glass missile, under the heading "Distance to impact," means that if you are 4.9 miles away from the center of the blast and the glass missile is 10 feet away from you——

Dr. WHITE. That arose 10 feet away from you. It started to move at that distance from you.

Senator HICKENLOOPER. It started to move a distance 10 feet away.

Dr. WHITE. It would have a velocity of 115 feet per second when it hit you.

Senator HICKENLOOPER. So that the 10 feet is not 10 feet from the point of blast.

Dr. WHITE. No.

Senator HICKENLOOPER. But the 10 feet from the point of casualty?

Dr. WHITE. The 10 feet refers to distance of missile travel before impact.

Senator HICKENLOOPER. Thank you. I just wanted to get that clear.

Dr. WHITE. Yes, sir. For the 10-pound masonry missile, also traveling 10 feet before impact with the target, the ranges were estimated at 4.6 and 11 miles for the two yields under consideration. If one allowed the 10-pound masonry missile for the one MT case to move until it reached a 10 feet per second maximum velocity, it would move 26 feet where the range was 4.9 miles. The same missile for the 10 MT case would reach a velocity of 10 feet per second after 58 feet of travel at 14 miles from the epicenter. This means that the overpressure would be lower if you allow the winds to act on the missile longer. It keeps accelerating until maximum velocity occurs. If one wants to put this in terms of range and keep the velocity at 10 feet per second, the farther you let the missile move—up until it gets maximum velocity—the less the overpressure and the greater the range.

The expected corresponding areas over which missile casualties could be expected were, for a glass missile, 10 grams in weight, again traveling 10 feet before impact: 75 square miles and 380 square miles for the 1 and 10 MT yields respectively. For masonry missile of 10 pounds, also moving 10 feet before impact at 10 feet per second, the corresponding areas involved were estimated at 66 and 380 square miles. If one lets the missile move 26 and 58 feet for the 1 and 10 MT case, respectively, the corresponding areas are 75 and 620 square miles.

Casualties due to displacement—among other things as was the case with the missiles—were noted to involve the distance of travel before impact.

Representative HOLIFIELD. You mean by displacement changing positions of the human body?

Dr. WHITE. I mean actual picking up of a man and moving him through the air. This concept allows one to "treat" man as a missile. We were fortunate enough at a 5 psi station in one of the 1957 shots in Nevada to photograph the time-displacement history of a 160-pound dummy, and were able from analysis of the movies to determine the maximal velocity reached by this "creature" at about 21 feet per second. This velocity developed in five-tenths of a second. The total displace-

ment of the dummy was near 22 feet downwind. It was this piece of empirical information that helped greatly in getting an analytical "handle" on the "treatment" of man as a missile.

Likewise in the Nevada experience on another shot, where the overpressure was about 7 pounds per square inch the maximal velocities reached by standing and prone dummies were not determined. But the total displacement of the standing dummy was 256 feet downwind and 44 feet to the right. ← PRECURSOR BLAST WAVE!

Representative HOLIFIELD. This is what size bomb, if you remember?

Dr. WHITE. I think I will ask Mr. Corsbie if he knows the yield of that shot.

Representative HOLIFIELD. Mr. Corsbie, do you remember that yield?

Mr. CORSBIE. That was a 43 kiloton fired from about a 700 foot tower. ⇒ PLUMBBOB – SMOKY 31 AUGUST 1957.

Representative HOLIFIELD. How far was the dummy from the tower?

Dr. WHITE. This was approximately—I may have to correct this—either 3,406 feet or 3,604 feet. The correct distance was 3,406 feet.

Representative HOLIFIELD. More than a half mile?

Dr. WHITE. The measured pressure there was 6.9 pounds per square inch and the pressure of the wind, which is the difference between the pressure measured head on to the advancing shock front and the pressure measured side on, was 15.4 pounds per square inch. For orientation it is useful to know that hurricane winds of about 120 miles an hour have a dynamic pressure or "Q" of approximately 0.2 of a pound per square inch. These are tremendous winds.

Representative HOLIFIELD. Then the wind is much greater than the worst hurricanes that have hit our coasts?

Dr. WHITE. Yes. This, ignoring other factors, is a function of the overpressured yield and the range, of course. The usual quoted dynamic pressure for 5 pounds per square inch for small yields is approximately 0.5 or 0.7 pound per square inch.

Representative HOLIFIELD. How high does it go in the case of a 10 megaton?

Dr. WHITE. I can't answer that out of my head. I would have to look it up. I don't think that the Q's associated with a given overpressure like 5 p.s.i. which will occur at considerable range will be much higher than for small yields. I am no blast physicist, but I think this is the case. But the winds, however, will last much longer.

Representative HOLIFIELD. Does the lower chart on page 33 mean that a body 5.5 miles from point zero would travel 28 feet?

Dr. WHITE. Yes, which is the best current estimate for the 1 MT surface burst. That range, of course, fixes an overpressure, but that range also "fixes" a velocity of 10 feet per second, which was adopted in the criteria. Ten feet per second was chosen as the velocity at impact for just beginning casualties based on what biological information is known about impact loads necessary to fracture the skull, to fracture the heel bones and the bones of the feet, and the lower extremeties.

Representative HOLIFIELD. And in the case of the 10-megaton bomb, a body would travel 58 feet over a range of 16 miles?

Dr. WHITE. At 16 miles.

STATEMENT OF DR. VICTOR BOND,[1] DIRECTOR OF THE DIVISION OF MICROBIOLOGY, MEDICAL RESEARCH CENTER, BROOKHAVEN NATIONAL LABORATORY

Dr. BOND. Thank you, Mr. Holifield.

Mr. Chairman, members of the committee, my topic is confined to the high-level fallout field itself, since, of course, beta lesions are not a problem in the absence of high-level fallout.

The relative importance of beta, compared to gamma radiation in fallout material in terms of casualty production, has been subject to debate. Before the accidental exposure of the Marshallese and the Japanese fishermen in March of 1954, the tendency was to ignore fallout in general, and beta radiation from fallout in particular, as formidable injurious agents.

The events in March of 1954 served to demonstrate conclusively, first, that high level radioactive fallout can result in extremely widespread serious injury and even death, and second, that extensive beta lesions of the skin can result, in the absence of a lethal exposure to penetrating gamma radiation, in an unprepared population exposed to large amounts of radioactive fallout.

In the time allotted me I propose to review the nature and the extent of skin damage that might result from exposure to large amounts of radioactive fallout. In doing this I shall rely rather heavily on the Marshallese data, although other examples are, of course, available. I shall do this since the data represent a well documented example of fallout beta lesions in a sizable population of human beings, and since I observed and helped care for the individuals involved and thus can speak from personal experience.

With respect to the lesions that we saw in the Marshallese, and I shall use the term "beta lesions" since a very large percentage of the dose received by the skin surface in these individuals resulted from beta radiation, the Marshallese were showered with radioactive fallout following the detonation in March 1954 of a high yield thermonuclear device during weapon testing in the Pacific proving grounds.

The wind shifted unexpectedly following the detonation, leading to unexpected fallout in significant amounts being deposited on the atolls of Rongelap, Rongerik, and Uterik.

---

[1] Born: Santa Clara, Calif., Nov. 30, 1919.

Education: San Jose High School, California, 1937; University of California, Berkeley, A.B., 1943; University of California, San Francisco, M.D., 1945; University of California, Berkeley, Ph. D. in medical physics, 1952.

Positions: Head, Experimental Pathology Branch, U.S.N. Radiological Defense Laboratory, San Francisco, Calif., 1948–54; scientist, Medical Research Center, Brookhaven National Laboratory, Upton, Long Island, N.Y., 1955–57; head, Division of Microbiology, Medical Research Center, Brookhaven National Laboratory, 1957 to present.

Military: Medical officer, U.S. Navy, 1945–54, highest rank, lieutenant, Marine Corps, U.S. Navy; presently, lieutenant commander, Marine Corps, U.S. Naval Reserve, retired.

Fields of interest: Medicine, radiobiology, effects of radiation. Twelve years of research experience on the effects of radiation, both in the laboratory and in field testing of atomic devices.

Other activities and information: Participant and project officer in biological work involving field testing; deputy director of the medical team that cared for the Marshallese following exposure to fallout radiation. In 1958, chairman of subcommittee on biomedicine, NAS–NRC, to evaluate adequacy of research in nonmilitary defense. Presently member of the National Advisory Committee on Radiation, Public Health Service; Subcommittee on Hematology of the NAS–NRC Committee To Investigate the Effects of Atomic Radiation; Subcommittee on RBE of the NCRP; Subcommittee on Radiological Dosimetry, ICRU.

Professional organizations: American Physiological Society, New York Academy of Sciences, Radiation Research Society, Sigma Xi, and AAAS.

Beta Radiation Skin Lesions (Beta Burns) From Fallout Radiations

DR. BOND:

INTRODUCTION

The relative importance of beta, compared to gamma radiation in fallout material in terms of casualty production has been subject to debate. Before the accidental exposure of the Marshallese (1) and the Japanese fishermen in March of 1954 (2), the tendency was to ignore fallout in general, and beta radiation from fallout in particular, as formidable injurious agents. The events in March of 1954 served to demonstrate conclusively, (1) that high-level radioactive fallout can result in extremely widespread serious injury and even death in an affected population, and (2) that extensive beta lesions of the skin can result, in the absence of a lethal exposure to penetrating gamma radiation, in an unprepared population exposed to large amounts of radioactive fallout. In this presentation the nature and extent of skin damage that might result from exposure to large amounts of radioactive fallout will be reviewed. In doing this heavy reliance will be placed on the Marshallese data (although other examples are available), since these data represent a well-documented example of fallout beta lesions in a sizable population of human beings, and since the author observed and helped care for the individuals involved and thus can speak from first-hand experience. Following this review of the nature of skin damage that can result from radioactive fallout, the possible degree to which the Marshallese situation might pertain under circumstances in the United States rather than in the mid-Pacific, and under circumstances in which the exposed population is better informed and better prepared, will be considered. Finally, an attempt will be made to place the potential beta lesion problem in perspective with regard to its seriousness compared to the hazard from the penetrating gamma radiation, which of course is invariably present.

THE MARSHALLESE INCIDENT

Now with respect to the beta lesions in the Marshallese (the affected areas are termed "beta lesions" since a very large percentage of the dose received by the skin surface resulted from beta radiation). These individuals were showered with radioactive fallout following the detonation in March 1954 of a high yield thermonuclear device during weapons testing at the Pacific Proving Grounds. The wind shifted unpredictably following the detonation, leading to unexpected fallout in significant amounts being deposited on the atolls of Rongelap, Rongerik and Uterik. The 64 Marshallese individuals on Rongelap at the time, 105 nautical miles from the detonation, received the largest exposure and I shall confine my remarks to this group. The fallout was visible on Rongelap, described as snowlike, and began falling approximately 5 hours after the detonation. The material was deposited on the ground and on the thatched-roof houses, as well as on the clothes, hair, and skin of the people. The individuals remained on the island for approximately 2 days, at which time they were transferred to the U.S. Naval Station at Kwajalein for medical observation.

No dosimeters were present on the island, and the doses of gamma radiation received were estimated from average readings of survey instruments held 3 feet above the ground, of the order of a week following the detonation. From these readings it was estimated that the Rongalapese received approximately 175 r. of penetrating gamma radiation, dose measured essentially free in air. In addition to gamma exposure, these individuals received large doses of beta radiation in areas of the body in which the fallout material was adherent to the skin. It is not possible to calculate with any reasonable degree of accuracy the dose to the skin from beta radiation. Estimates involving the known minimal dose of radiation to cause hair loss or epilation indicate that the surface of the skin probably received of the order of 5,000 or more rads.

With regard to symptomatology, with the exception of nausea in some two-thirds of the individuals during the first 2 days, and vomiting and diarrhea in a smaller percentage, no symptoms developed that could be ascribed to penetrating gamma radiations. However, the penetrating radiation did result in marked peripheral blood count changes. No deaths occurred as the result of irradiation and all signs and symptoms except the initial gastrointestinal symptoms referred to were related to beta lesions of the skin.

CALCIUM HYDROXIDE FALLOUT

Within the first 2 days of exposure a number experienced transitory itching and burning of the skin, and some complained of lacrymation. No further signs or symptoms referable to the skin were noted until about 2 weeks after exposure,

when skin lesions and epilation, or loss of hair, was noted. Approximately 90 percent of the individuals showed some damage of this nature to the skin, and a smaller number showed spotty epilation. The skin lesions first appeared as small, raised pigmented areas, which later coalesced to form more extensive lesions. The nature of these lesions is indicated in figures 1 to 6 (pp. 384 to 389). Most of the lesions were superficial and exhibited dry desquamation or loss of skin surface much like a fairly severe sunburn. Essentially all lesions were located in skin areas not covered by clothing, and they were most prevalent in the folded areas of skin where perspiration would tend to collect. Even thin clothing apparently served to prevent visible damage. The superficial lesions required no therapy beyond bland, soothing preparations, and apparently complete healing occurred within a few weeks. Some of the lesions were deeper, however, and showed wet desquamation or loss of skin. Such lesions became infected, and required treatment with antibiotics. The affected areas, with the exception of one, also healed in a matter of weeks, with some residual scarring, atrophy and depigmentation. On followup examinations in the 5 years since the accident (3–7), none of the lesions has shown a tendency to break down, nor has premalignant or malignant change occurred.

In the course of initial observation it was not necessary to hospitalize any of the patients. Some itching, but no pain was associated with the superficial lesions; however by no standard could these people be considered incapacitated. Mild pain was associated with the deeper lesions and some difficulty with walking resulted with the deeper lesions located on the feet. Here also, however, it would have been difficult to classify these individuals as incapacitated. If necessary, they could have performed essentially any task associated with daily living and survival.

APPLICATION OF THE MARSHALLESE RESULTS TO FALLOUT SITUATIONS IN GENERAL

So much for the Marshallese accident indicating that extensive beta skin lesions can occur in the face of sublethal gamma exposure; now let us consider to what degree the Marshallese incident may be considered typical of what might occur in case of widespread fallout in populated areas of the United States from deliberate attack, or from accidental nuclear weapon detonation. And I wish now to make it perfectly clear that I speak of a disaster situation, not routine peacetime operations and certainly not the long-range fallout that has resulted in essentially worldwide, very low-level contamination. There are several factors that would make one consider the Marshallese incident the worst that could reasonably pertain with respect to the hazard of beta radiation relative to that of gamma radiation (of course, populations might be exposed to considerably larger doses of both beta and gamma radiation than were the Marshallese). These people were not alerted to the possible hazards of fallout and had no comprehension of what was happening; thus they took no evasive action and made no effort to decontaminate themselves. American servicemen on a nearby contaminated island, who were more alert to the danger and added clothing and decontaminated themselves showed considerably less effect than did Marshallese comparably exposed. The Rongalapese were not evacuated from the contaminated island, and thus were not decontaminated for 2 days, at which time a large percentage of the dose from the rapidly decaying fission products had been received. It is clear that the great bulk of the beta dose was derived from material deposited on the skin, and the habits of the Marshallese tended to maximize the deposition of the material on the skin. They wore rather scanty clothing and no shoes, and spent a good deal of time out of doors. The use of thick hair oil aided in collecting the material on the head. The high humidity and sweating contributed by encouraging the material to collect on the skin. Thus one might conclude that the beta lesions would constitute an extensive problem only under the rather favorable conditions for it that were present in the Marshallese, and that the problem would essentially not exist should an American city be subjected to fallout radiation. And further, one could conclude that since beta skin lesions might be classified more as a minor effect and a nuisance rather than an incapacitating or deadly one, that one might essentially ignore the problem in the face of the known serious consequences of the penetrating gamma radiation and other potentially lethal modalities. This evaluation could pertain; however, it is necessary to inject a word of caution.

It is quite true that Americans spend a good deal of time inside; however, under some circumstances (warmer regions, summertime) sizable numbers could be outside, with portions of the skin exposed. Also, especially in the peripheral zone from the point of detonation where windows may be shattered without other serious structural damage, it may not be necessary to be outside to have material deposited on one. Fallout on a previously devastated area would present a like picture. The fallout was visible in the Marshalls; it might not be in continental surroundings. Even a thin layer of clothing protected the Marshallese from visible damage from fallout from the particular device employed. I do not know to what degree the beta energy spectrum from this device would represent closely that from more recent devices. One cannot ignore the possibility of fallout coming down in rain, in which event clothing, if not removed, might provide the ideal situation for severe beta lesions. It is entirely possible under the chaotic conditions that would exist following attack that no facilities for adequate decontamination may be available. An educated, prepared population under almost any circumstances can do much to lessen the degree of damage or avoid damage completely; however, in the author's opinion, the vast majority of Americans are neither prepared for, nor educated to the danger of fallout in general, let alone the possible hazard from beta radiation.

The main point to be made from the above remarks is that while beta lesions, considered in the overall possible casualty situations, undoubtedly is a lesser consideration, it is still possible that appreciable segments of the involved population might develop beta lesions if exposed to fallout and no preventive measures were taken. If this be the situation, the results potentially could be more serious than in the Marshallese, and much more than a mere nuisance, for the following reasons: in the Marshallese, while the white count of the blood was markedly depressed, this and other immune mechanisms apparently were never impaired to the point at which the individual was not able to ward off possible invading organisms. Further, the point of maximum effect on the white count occurred relatively late, in the fifth and sixth week, after the beta lesions were well on the way to healing. With a larger dose of gamma radiation, and had the Marshallese been only a few miles further north than they were at the time of fallout they would have received a considerably larger dose, the situation might have been different. The white count would have fallen faster, and it and other immune mechanisms would have been seriously affected. Then more of the lesions might have become infected, and in addition the open lesions would provide a portal of entry for invading organisms, leading potentially to generalized infection. Infection is the problem of perhaps greatest magnitude with massive total body gamma exposure, and with open skin lesions many might succumb that otherwise might survive. This especially under conditions that undoubtedly would pertain, in which no, or inadequate, medical care would be available. Thus, at present, I do not think we should ignore completely the beta lesion problem.

In summary, there can be no doubt that in a fallout field, within hours and perhaps days of detonation, penetrating gamma radiation is the controlling hazard. Gamma radiation is the agent that kills primarily. However, there also is no doubt that extensive beta lesions have occurred, and might occur under some conditions in a fallout field. In an unprepared population unaware of the potential danger, beta skin lesions could represent a potentially serious hazard to appreciable numbers of individuals exposed. In a well-prepared population educated to the potential hazard, the beta skin lesion problem would be minimal indeed.

SUMMARY

The Marshallese accident in March 1954 demonstrated clearly that extensive beta lesions of the skin, in the absence of a lethal dose of gamma radiation, can occur under some conditions in an unprepared population exposed to a high-level fallout radiations. The fallout began on Rongelap Atoll in the Marshall Islands approximately 5 hours after the detonation of a high yield thermonuclear device, and the 64 individuals on this atoll were evacuated approximately 2 days later. An estimated 175 r. of penetrating gamma radiation was delivered to the entire body, in addition to large doses of beta radiation to exposed areas of skin to which the fallout material clung. Beginning approximately 2 weeks after exposure, lesions of the skin appeared on some 90 percent

of the individuals. The affected areas included the head, and other locations where the material had deposited. Most of the lesions were superficial and healed rapidly. Some were deep and painful, and healed more slowly with some residual scarring. There has been no evidence to date of secondary breakdown or malignant change in these lesions.

Several factors pertained that made the Marshallese incident possibly the worst that could happen with respect to the relative importance of the beta hazard under conditions of fallout (of course populations could be exposed to much larger total doses of both beta and gamma radiations than were the Marshallese). The people were not educated nor prepared for the danger, and prolonged exposure without evasive action or decontamination occurred. The climatic conditions, conducive to relatively scanty clothing and outdoor existence also increased the degree of exposure. Under conditions of living in a temperate climate, many of these adverse factors would not normally be operative, and thus the beta problem would be expected to be minimal. However, it must be pointed out that exposure to contact beta radiation of a sizable number of individuals might occur in an uninformed population under some conditions (area of milder climate or in summer, individuals in buildings with shattered windows, fallout on a previously devastated area, clothed individuals caught in radioactive rain), or under chaotic conditions in which decontamination might not be possible. In these affected individuals, in the absence of decontamination, the resultant skin lesions in some could be much more serious than those seen in the Pacific islands. If the concomitant gamma exposure were higher than that received by the Marshallese, which it could easily be, the resultant depression of the white blood cell count, and of other immune mechanisms necessary to combat infection would be correspondingly more severe. Under these circumstances the open skin lesions could serve as a portal of entry for organisms, leading potentially to fatalities in individuals that might otherwise survive. Thus while the penetrating gamma hazard would by all odds be the most lethal agent in a fallout field, the beta skin hazard cannot be ignored and must be guarded against. Only in a population that is informed of the potential danger and is prepared will beta hazard be reduced to a minimum.

REFERENCES

1. Cronkite, E. P. et al. The Effects of Ionizing Radiation on Human Beings: A Report on the Marshallese and Americans Accidentally Exposed to Radiation from Fallout and a Discussion of Radiation Injury in the Human Being, U.S. Government Printing Office, Washington, D.C., 1956.

2. Tsuzaki, M. Radioactive Damage of Japanese Fishermen Caused by Bikini Ashes. Munch.med.Wochschr., 97: 988–94 (1955). Also, Proceedings of First International Conference on Peaceful Uses of Atomic Energy, Geneva, 1955 (United Nations).

3. Bond, V. P., Conard, R. A., Robertson, J. S., and Weden, E. A., Jr. Medical Examination of Rongelap People 6 months After Exposure to Fallout, WT–937, Operation Castle Addendum Report 4.1 A, April 1955.

4. Cronkite, E. P., Dunham, C. L., Griffin, D., McPherson, S. D., and Woodward, K. T. 12-Month Postexposure Survey on Marshallese Exposed to Fallout Radiation, BNL 384 (T–71), August 1955.

5. Conard, R. A., Huggins, C. E., Cannon, B., Lowrey, A., and Richards, J. B. Medical Survey of Marshallese 2 Years After Exposure to Fallout Radiation, J.A.M.A. 164, 1192–7 (1957).

6. Conard, R. A., Meyer, L. M., Rall, J. E., Lowrey, A., Bach, S. A., Cannon, B., Carter, E., Eicher, M. and Hechter H. March 1957 Medical Survey of Rongelap and Utirik People 3 Years After Exposure to Radioactive Fallout, BNL 501 (T–119), June 1958.

7. Conard, R. A., Robertson, J. S., Meyer, L. M., Sutow, W. W., Wolins, W., Lowrey, A., Urschel, H. C. Jr., Barton, J. M., Goldman, M., Hechter, H., Eicher, M., Carver, R. K., and Potter, D. W. Medical Survey of Rongelap People, March 1958, 4 Years After Exposure to Fallout, BNL 534 (T–135) (1958).

FIGURE 1

FIGURE 1.—Extensive lesions, 46 days after exposure, on a young boy who wore little clothing at the time of exposure. Note particularly the lesions on the neck, in the armpits and at the beltline—areas where the fallout material tended especially to collect.

FIGURE 2

FIGURE 2.—Extensive neck lesions on a woman approximately 30 days after exposure. Note the superficial nature of the lesions, resembling severe sunburn.

FIGURE 3

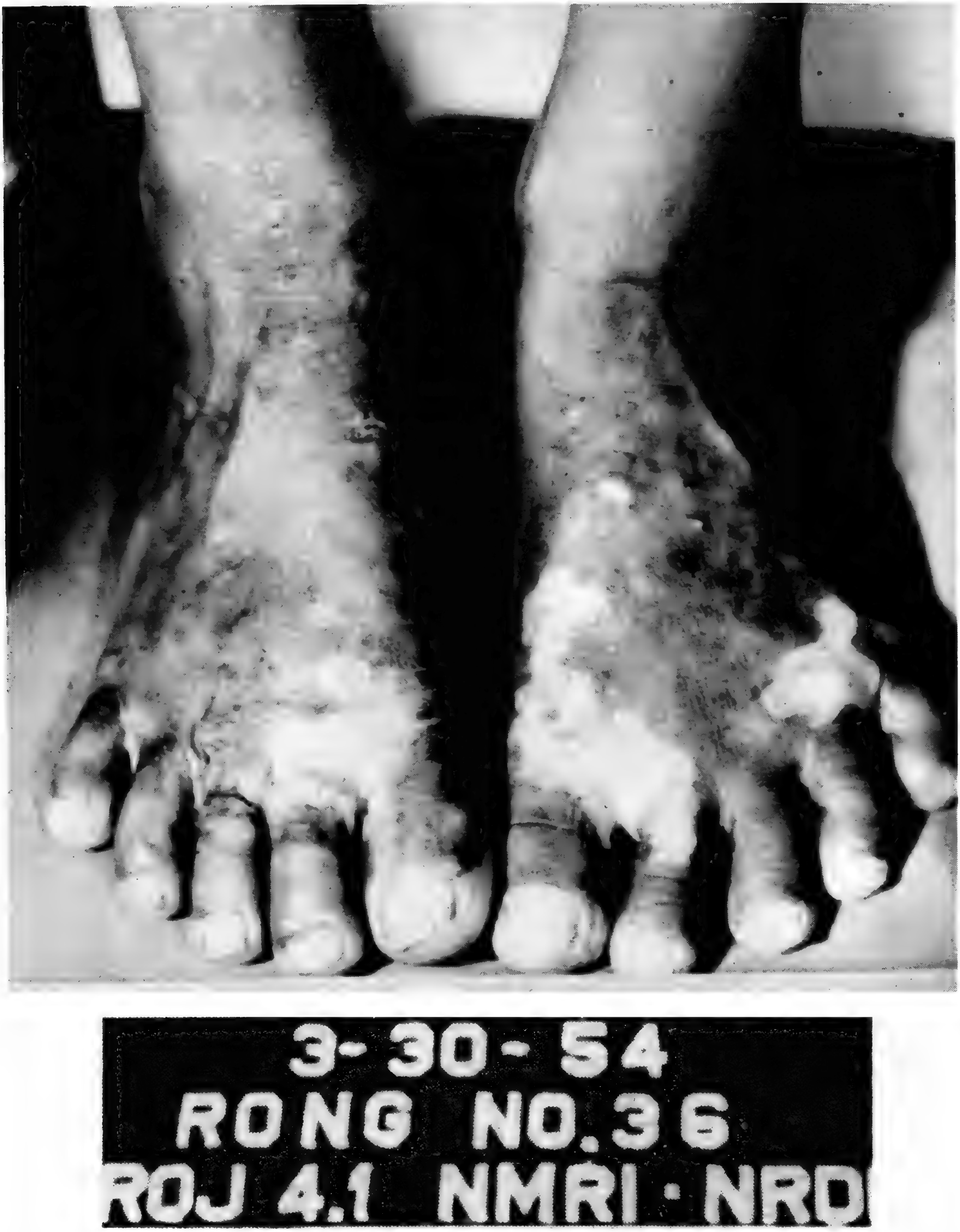


FIGURE 3.—Deeper, more severe lesions that healed more slowly.

FIGURE 4

FIGURE 4.—The same lesion shown in figure 3, 6 months later. Healing is complete, with residual scarring, atrophy, and depigmentation.

FIGURE 5

FIGURE 5.—Head lesions, and spotty epilation in a young girl 28 days after exposure.

FIGURE 6

FIGURE 6.—Complete regrowth of normal hair in the same girl shown in figure 5, 6 months after exposure.

Representative HOLIFIELD. At this point I would like to submit for the record, a statement by Dr. Conard, and his associates on the Medical Survey of the Rongelap People, March 1958, 4 years after exposure to fallout; and the report of the Medical Status of the Rongelap People 5 Years After Exposure to Fallout Radiation, by Dr. Conard, head of the Marshall Island surveys.

(The material referred to follows:)

MEDICAL SURVEY OF RONGELAP PEOPLE, MARCH 1958, FOUR YEARS AFTER EXPOSURE TO FALLOUT

ROBERT A. CONARD, M.D.,[1] JAMES S. ROBERTSON, M.D., PH.D.,[1] LEO M. MEYER, M.D.,[2]
WATARU W. SUTOW, M.D.,[3] WILLIAM WOLINS, M.D.,[1] AUSTIN LOWREY, COL. (MC) USA,[4]
HAROLD C. URSCHEL, JR., LT. (MC) USN,[5] JOHNNY M. BARTON, CAPT. (MC) USAF,[6]
MORRIS GOLDMAN, PH.D.,[7] HYMAN HECHTER,[8] MAYNARD EICHER,[5]
RUSSELL K. CARVER,[7] AND DAVID W. POTTER[1]

with the technical assistance of

CLYDE R. SIPE,[1] JAMES S. OTTO, HMC, USN,[9] MARION L. HARTLEY, HMC, USN,[5]
PACIFICO A. TENORIO, HMI, USN,[5] WILLIAM G. MURRAY,[8]
WILLIAM A. SCOTT,[1] AND IRVING JONES[2]

[1]Brookhaven National Laboratory, Upton, New York
[2]South Nassau Communities Hospital, Rockville Centre, New York
[3]M.D. Anderson Hospital, University of Texas, Houston, Texas
[4]Walter Reed Army Hospital, Washington, D.C.
[5]Naval Medical Research Institute, Bethesda, Maryland
[6]Armed Forces Special Weapons Project, Washington, D.C.
[7]Communicable Disease Center (Public Health Service), Chamblee, Georgia
[8]Naval Radiological Defense Laboratory, San Francisco, California
[9]Naval Medical Center, Bethesda, Maryland

BROOKHAVEN NATIONAL LABORATORY
Upton, N. Y.

Report BNL-534,
May 1959.

MEDICAL SURVEY OF RONGELAP PEOPLE, MARCH 1958, FOUR YEARS AFTER EXPOSURE TO FALLOUT

Background

This report presents the results of a medical survey carried out in March 1958 on the Marshallese people of Rongelap Atoll who were accidentally exposed to radioactive fallout in March 1954. The accident occurred following the detonation of a high yield thermonuclear device during experiments at Bikini in the Pacific Proving Grounds. An unpredicted shift in winds caused a deposition of significant amounts of fallout on four inhabited Marshall Islands nearby and on 23 Japanese fishermen aboard their fishing vessel, the Lucky Dragon (see Figure 1.) Sixty-four inhabitants of the island of Rongelap, 105 nautical miles away from the detonation, received the largest fallout exposure: an estimated dose of 175 r whole-body gamma radiation, beta burns and epilation from contamination of the skin, and slight internal absorption of radioactive material. Another 18 Rongelap people away on a nearby island (Ailingnae), where less fallout occurred, received only about half this exposure. Twenty-eight American servicemen on the island of Rongerik further away received about the same amount of radiation as did the 18 people on Ailingnae (about 70 r). Lastly, 157 Marshallese on Utirik, about 200 miles distant, received only about 14 r whole-body radiation. The fallout was not visible on this island and no skin effects were seen.

The exposed people were evacuated from these islands by plane and ship about two days after the accident and taken to Kwajalein Naval Base about 200 miles to the south, where they received extensive examinations for the following 3 months. In view of the generally negative findings on the American servicemen, they were returned to their duty stations. The Utirik people were repatriated to their home island, where the radioactivity was considered to be low enough for safe habitation. Because Rongelap Atoll was considered to be too highly contaminated, a temporary village was constructed for the Rongelap people on Majuro Atoll several hundred miles to the south, where they remained for the following 3½ years. In July 1957, after careful evaluation of remaining radiological hazards, Rongelap Island was found safe for habitation. A new village was constructed, and the Rongelap people were moved there by Navy ship. The present survey was therefore carried out at Rongelap Island.

SUMMARY OF PAST FINDINGS

Reports have been published on the findings of surveys made at the following times after exposure: initial examinations,[1] 6 months,[2] 1 year,[3] 2 years,[4] and 3 years.[5] The following is a brief summary of these findings.

During the first 24 to 48 hr after exposure, about ⅔ of the Rongelap people experienced anorexia and nausea. A few vomited and had diarrhea. Many also experienced itching and burning of the skin and a few complained of lachrymation and burning of the eyes. Following this, these people remained asymptomatic until about 2 weeks after the accident, when cutaneous lesions and loss of hair developed due largely to beta irradiation of the skin. It was apparent when the people were first examined, a few days after exposure, that the lymphocytes were considerably depressed and that significant doses of radiation had probably been received. In addition to the whole-body dose of radiation and the beta irradiation of the skin, radiochemical analyses of the urine showed that significant amounts of radioactive material had also been absorbed internally. The effects of the radiation can best be summarized under three headings according to the mode of exposure: penetrating irradiation, skin irradiation, and internal irradiation.

Penetrating Irradiation

The changes in the peripheral blood of the more heavily exposed Rongelap people who received 175 r will be reviewed below (see Figures 7, 9, 12 and Tables 3, 4, 5). The changes in the Ailingnae and Utirik groups were similar but less marked. Certain unexplained fluctuations have occured from year to year in the peripheral blood levels of the comparison populations as well as of the exposed groups. Depression of the peripheral blood elements as represented by mean population levels occurred as follows.

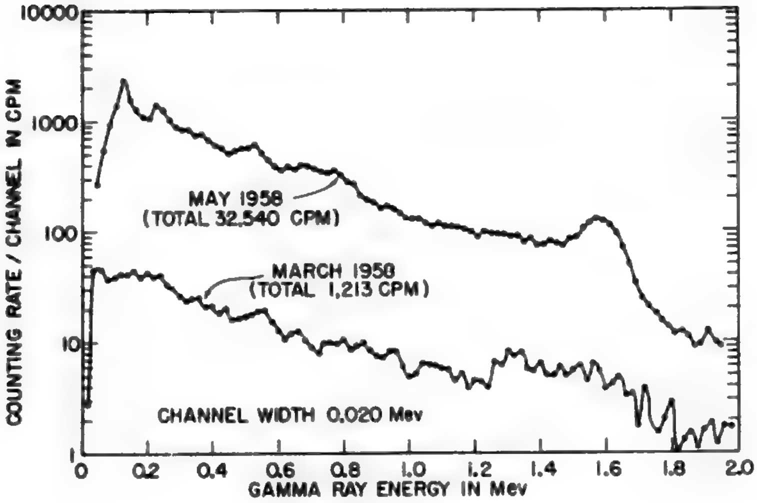


Figure 16. Background counting rates at Rongelap Atoll.

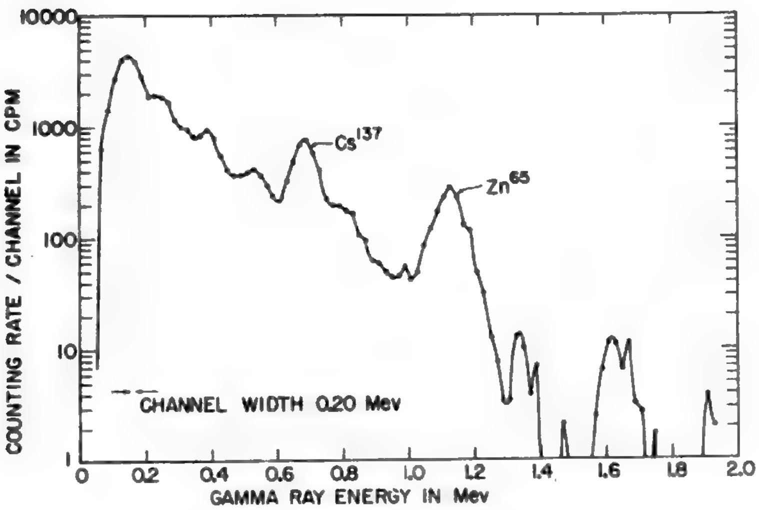


Figure 17. Rongelap subject #50, May 1958, total 43,260 cpm above background.

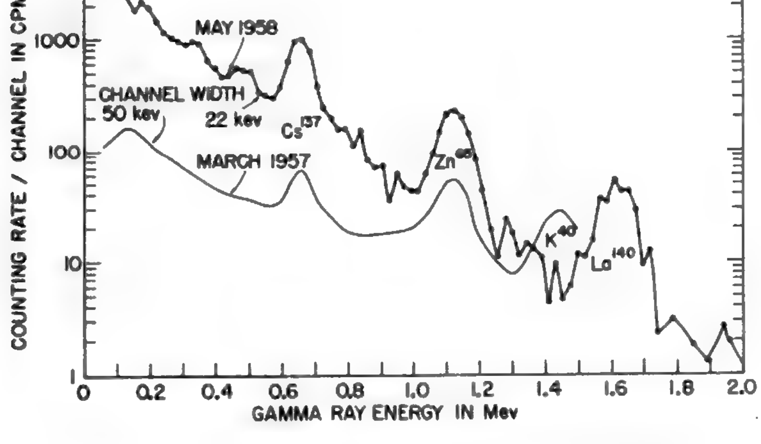


Figure 18. Rongelap subject #79, total 66,974 cpm above background (analysis No. 4).

Findings. Figure 16 compares the background gamma-ray spectrum of March 1958 with that of May 1958. (A few background data, plant and marine specimens, and data on one of the American subjects had been carried separately and hence were not lost at sea.) In addition to its being high, the May background shows a peak at 1.6 Mev, which was attributed to Ba-La^{140}. Except for this one peak, the background spectrum is essentially continuous. This, plus the fact that external procedures were effective in reducing the background, whereas cleaning the inside of the steel room and removal of unnecessary articles from within the room were ineffective, indicated that the contaminating radioactivity was outside the room.

Figure 17 shows the net gamma-ray spectrum of a representative Marshallese subject after appropriate correction for analyzer dead time and subtraction of the background. The Cs^{137} and Zn^{65} peaks are seen to be prominent, and in this case there is also a net peak at 1.6 Mev which has been attributed to Ba-La^{140} and which obscures the K^{40} peak. The latter was not a constant finding, but even in the spectra without it, the K^{40} peak was usually obscured by the high background. It had been hoped that the spectra could be examined for other peaks, but, since the method of analysis requires the high energy peaks and their associated Compton scattering spectra to be subtracted out first, the difficulties introduced by the high background, the 1.6 Mev peak, and the masking of the K^{40} peak render the entire procedure very uncertain. Similar difficulties prevented examination of the spectrum for possible contributions from Sr^{90} bremsstrahlung. If future surveys show the presence of additional nuclides, the 1958 data may be re-examined. For the present, however, only the Cs^{137} and Zn^{65} values, based on peak heights, are reported here.

Figure 18 shows the spectrum for another subject in 1958 compared with his spectrum in 1957. Because of the narrower channel width used in the 1958 study, the activities are even higher relative to the 1957 levels than the graph indicates.

The body content of Cs^{137} and Zn^{65} and the urinary concentrations of Cs^{137}, Zn^{65}, K^{40}, and Sr^{90} are presented in Table 15. Since the urine specimens were obtained in March, they may not correspond strictly to the body data obtained in May. The subjects are divided into groups on the basis of their island of residence. The data are presented in this way rather than on the basis of exposure

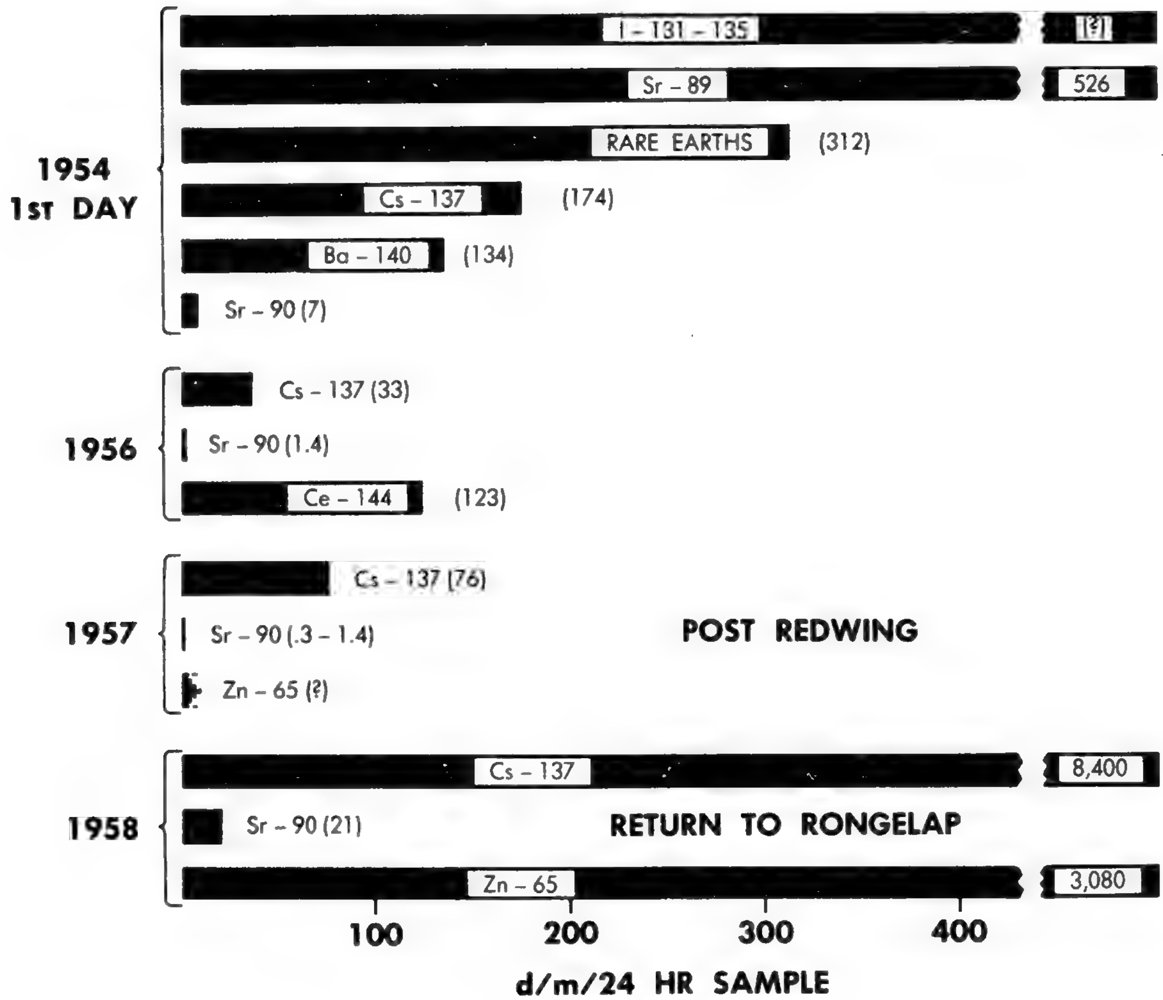


Figure 19. Urinary excretion of isotopes by Rongelap people.

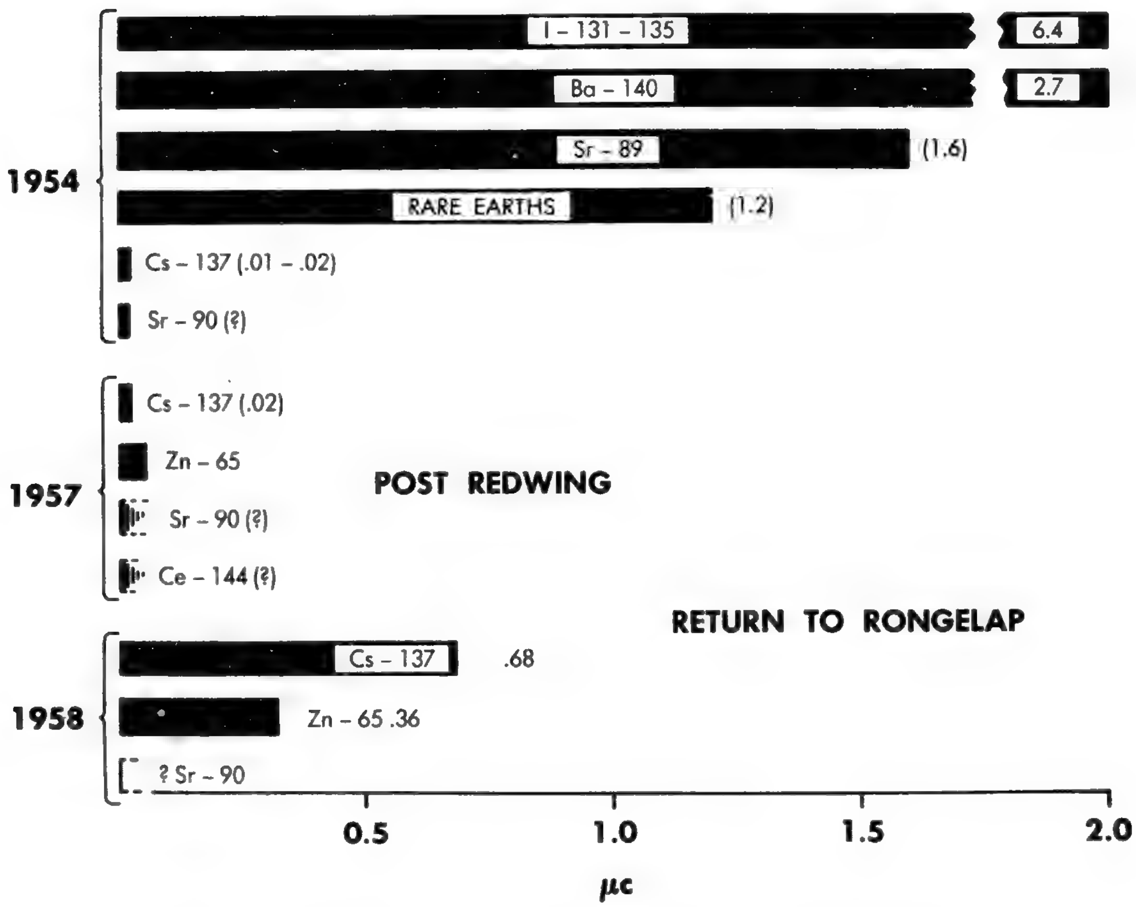


Figure 20. Estimated body burden of isotopes of Rongelap people.

Medical Status of Rongelap People 5 Years After Exposure to Fallout Radiation

Robert A. Conard, M.D., Head, Marshall Island Medical Surveys

In March 1959 the regular annual medical survey was carried out on the Rongelap people who had received the heaviest exposure to radiocative fallout 5 years previously in the accident which occurred following the experimental detonation of a nuclear weapon.

The examinations were conducted on Rongelap Island to which the people had returned in July 1957. On their return, they were accompanied by an equally large group of unexposed relatives. This latter group has served as a comparison population for the medical studies. The Navy kindly furnished an LST for the survey.

These annual surveys are carried out under the direction of Brookhaven National Laboratory and sponsored by the Atomic Energy Commission with the support of the Trust Territory of the Pacific Islands, the Department of Defense, and other governmental agencies. A team of 20 physicians, scientists, and technicians, specialists in the field of radiation medicine, carried out the survey on Rongelap Island.

On arrival of the team at Rongelap there was some question in the minds of some of the people as to the necessity of having further examinations. Objections to the examinations were mainly directed toward their dislike of the blood sampling. It was also evident that the need for the examinations created some concern in the minds of the people about their health status. Some also were concerned about the radiological safety of their food and water for consumption. The people were reassured that their health was generally good and their food and water safe for consumption, and the importance of continued examinations and treatment in order to help insure their continued good health was stressed. These explanations appeared to alleviate their fears and the people cooperated extremely well with the medical team in carrying out the examinations. ← LED TO SERIOUS DISTRUST IN 1980–PRESENT!

The examinations included medical histories, complete physical examinations, and blood and other laboratory examinations. In addition spectrographs of gamma ray activity were obtained from individuals measured in a steel room and from radiochemical analysis of urine samples in order to determine their body burdens of radionuclides. Analyses of the data are not complete and those data referring to this recent survey must be considered as preliminary in nature. In conjunction with the examinations, considerable medical and dental treatment of the people was carried out to the extent possible under field conditions.

Following the accident, the Rongelapese had shown signs of significant exposure to radiation such as short-lived loss of appetite, nausea, vomiting, depression of their blood forming tissues, multiple burns of the skin from beta exposure and internal absorption of fission products.

Findings on the past survey revealed that the people have recovered from the acute effects of their radiation exposure. No diseases, illnesses, or deaths have occurred which could be directly related to their radiation exposure. The incidence of all diseases noted has been about the same in both the exposed and unexposed groups examined. The general physical condition of the exposed and unexposed people on the island appeared good and their nutritional status was satisfactory. During the past year one death occurred in a 35-year-old man, bringing the total deaths in the exposed group to 3 for the 5-year period. This represents a death rate about equal to that of the Marshall Islands as a whole (about 7 deaths per 1,000 population per year).

Findings, previously reported, which were interpreted as suggestive of a slight lag in growth and development of the children during the first few years after exposure are being reevaluated based on more exact age data obtained on the past survey. The results of this evaluation are not complete enough to make any statements at present.

One case of cancer (ovarian) developed in a 61-year-old female during the past year, the first case of cancer noted in either the exposed or unexposed populations. There is no reason to believe the cancer is related to radiation effect.

Fertility does not appear to have been affected since the birthrate has been higher in the exposed than in the unexposed Marshallese. A somewhat increased prevalence of miscarriages and stillbirths has been noted in the exposed group, but due to the paucity of vital statistics on the Marshallese and the small number of people involved, no statistical analysis is possible.

Recovery of the blood-forming tissues is judged virtually complete based on studies of the peripheral blood counts. A possible exception is seen in the blood platelets which are slightly below the levels in the unexposed group but still within the normal range. There is no evidence of any untoward effect associated with this finding.

The beta burns of the skin healed rapidly during the first few months after exposure. In 12 cases there remain slight scarring of the skin and pigment changes at the former site of deeper burns. However, no evidence of any cancerous change in these scars is noted. In those that lost hair, regrowth of normal hair was complete by 6 months after exposure.

Very little is known about late effects of radiation in human beings. Increased incidence of leukemia in the exposed Japanese people has been noted and, in animal studies, the following late effects of radiation may result: Life shortening, premature aging, increase in degenerative diseases, increased incidence of malignancies, opacities of the lens of the eyes, and genetic changes. The Marshallese have been examined for evidence of such changes, but none have been seen. Radiation-induced leukemia is known to appear relatively soon after exposure and other types of malignancy at later times. Therefore, continued examination are essential in order to detect and, if possible, treat such effects should they develop.

The radioactive fission products that had been absorbed internally by the Rongelap people were never sufficient in amount to result in acute effects. These radioactive materials were excreted rapidly during the first 6 months after exposure. The island of Rongelap remains slightly radioactively contaminated, but careful surveys showed the island to be safe for habitation by the summer of 1957 when the people were returned to Rongelap. Studies of the body burdens of radioactive materials in these people is an important part of the medical surveys. A 21-ton steel room with very sensitive radiation-detecting equipment has been used in the past two annual surveys at Rongelap to determine the body burdens of radionucleides. In addition numerous urine samples have been analyzed for radioactivity. The results of these studies show that there has been an increase in body burdens, principally of cesium 137, zinc 65, and strontium 90 since their return to Rongelap. About the same levels of these isotopes have been noted in those exposed and unexposed.

During the first 8 months after their return to Rongelap their body burden of cesium 137 are estimated to have increased by factors up to 100 (resulting in a mean body burden of 0.68 μc); zinc 65 is estimated to have shown a concomitant increase (mean body burden of 0.36 μc); strontium 90 showed about a twentyfold increase rate of excretion in the urine. Only one sample of bone is available for estimating the body burden of strontium 90. This is from a Rongelap man who died in April 1958 (9 months after his return to Rongelap) which showed 3.6 $\mu\mu c/Sr^{90}/gm$ Ca (strontium units). On the basis of North American data, it is expected that the values for children would be higher.

Based on preliminary analysis of data from the most recent survey (8 to 20 months after their return to Rongelap), it appears that the people have begun to attain equilibrium with their lightly contaminated environment. The cesium 137 levels appear to be slightly lower than the year before, while the zinc 65 has increased slightly. The strontium 90 analyses, unfortunatley, are not available yet. The body burdens estimated above are far below the maximum permissible levels; cesium 137 is about 2 percent of the MPL, and zinc 65 is 1 percent of the MPL.

In summary, a medical survey of the Marshallese people in March 1959, 5 years after exposure to fallout radiation, showed that the people had recovered from the acute effects of their radiation exposure and appeared to be generally in good health. The following specific statements can be made in regard to their radiation health status:

1. No illnesses or diseases were found that could be directly associated with acute radiation effects.
2. One case of cancer and three deaths have occurred, but with no direct relation to radiation effects.
3. Fertility does not appear to have been affected. The incidence of miscarriages and stillbirths appears to be somewhat higher than in the unexposed Marshallese, but a deficiency of vital statistics precludes definite conclusions as to whether or not this is a radiation effect.
4. Suggestive evidence of slight lag in growth and development of exposed children noted previously is being reevaluated on the basis of better age data obtained during the past survey.

5. Blood platelet levels are within the normal range but somewhat below those of the unexposed population.

6. Only 12 cases show residual changes in the skin from beta burns. None show any evidence of cancerous change.

7. Possible late effects of radiation such as shortening of lifespan, premature aging, increased incidence of leukemia and malignancies, increased incidence of degenerative diseases, opacities of the lens, and genetic changes have not been observed.

8. The original body burdens of internally absorbed fission products appears to be too low to have produced any acute or long-term effects.

9. The return of the people to the slightly contaminated island of Rongelap has caused some increase in body burdens of cesium 137, zinc 65, and strontium 90. However, the levels are far below the accepted maximum permissible dose and it is not believed any untoward effects will result.

In view of the limited knowledge of the late effects of radiation in human beings, it is considered essential that medical surveys of the Rongelap people continue to be carried out in order to detect and treat immediately any possible further effects of radiation that might develop. Though body burdens of radioactive isotopes are well below the accepted permissible dose levels and no further significant increase in these burdens is anticipated, a close check on these levels during future medical surveys is indicated.

(Whereupon, at 12:30 p.m., the committee recessed, to reconvene at 2 p.m., the same day.)

AFTERNOON SESSION

Representative HOLIFIELD. The committee will be in order.

Our first witness will be Dr. Gordon Dunning of the Division of Biology and Medicine of the AEC. Dr. Dunning will present a short summary of the effects of injection. We will accept his detailed statement for the record, and insert it at the end of his testimony.

Representative HOLIFIELD. Dr. Dunning, the Chair wishes to apologize for the necessity of asking you to summarize your testimony. As you can see, we are running late. We are going to have to carry over some of our witnesses until Friday morning. In the morning we plan to start on article X of the outline, which will have casualty estimates, human beings in the United States, and article XIII. We will try to cover that on Thursday. If we fail to get to some of the witnesses between now and then, we are going to have to carry over. We are running behind, and we have made commitments to members and others to have such data as is available on Thursday.

So at this time, Dr. Dunning, we will ask you to proceed.

TESTIMONY OF DR. GORDON M. DUNNING,[1] DIVISION OF BIOLOGY AND MEDICINE, ATOMIC ENERGY COMMISSION

Dr. DUNNING. Mr. Holifield, in my written testimony I have covered the subject of ingestion, what organs are most greatly affected, the relative amount of exposure to these organs, and the possible biological effects. I will summarize the principal statements in this written record.

[1] Date and place of birth: September 11, 1910; Cortland, N.Y. Education: State Teachers College, Cortland, N.Y., 1929–33; New York University (6 weeks), 1933; State Teachers College, Cortland, N.Y., 1934–36; M.S. (Sci. Edu..), Syracuse University, 1941; doctor of education, 1948. Work history: Teacher, Middletown, N.Y., 1937–41; U.S. Army (lieutenant colonel), 1942–46; instructor, New York Agricultural and Technical Institute, Alfred, N.Y., 1947–48; teacher, Phy. and Phy. Sci., Indiana, Pa., 1948–51; AEC, Biophysics Ren. Anal. Div. B. & M., 1951–53; AEC, Biophysicist, Division of Biology and Medicine, 1953–55; AEC, Radiation Effects Specialist, Division of Biology and Medicine, 1955—.

DR DUNNING:

Iodine-131

1. 2 KT/mi^2 -----> 2×10^5 curies I^{131}/mi^2

-----> 7.7×10^4 μc I^{131}/M^2

2. Based on Windscale experience

1 μc I^{131}/M^2 -----> 0.1 μc I^{131}/liter of milk(5)

For one liter of this milk -----> 2 rad dose to infant's thyroid.*

For continuous consumption of milk from cows grazing on pasture until I^{131} activity essentially zero -----> 22 - 44 rad dose.*

3. Arithmetically -

(7.7×10^4) (22-44) -----> $(1.7\text{-}3.4) \times 10^6$ rads total dose to thyroid of children.

4. Based on data from nuclear weapons tests, the cow's thyroid might theoretically receive a dose two orders of magnitude higher than the numan.(6)

Actually, of course, the external gamma exposure and the dose to the cow's digestive organs would guarantee its death. If milk were obtained before its death there might be enough I^{131} activity in a single pint of milk to completely destroy the infant's thyroid.

(7.7×10^4) (1-2 rads) -----> $(7.7\text{-}15) \times 10^4$ rads

The short-lived isotopes of radioiodine could contribute more dose to the thyroid than does I^{131} for the first day or so, but their activity would decrease rapidly with time.(7) Milk as a food item should be avoided until the iodine activity levels dropped to acceptable limits, or canned or powdered milk (prepared before the fallout occurred) should be substituted.

5. If one assumes all contaminated milk is eliminated from the diet there remains the general I^{131} contamination of the environment including exposed foods and water.

The principal potential source of intake of the I^{131} would be leafy vegetables and other similarly exposed foods. This I^{131} contamination would be reduced by washing the foods, since the water supply would be expected to contain less I^{131} activity due to dilution factors. However, the reduction would have to be considerable since a single intake of I^{131} from one square meter of surface during the first week after the fallout occurred might produce a thyroid dose of more than 10^5 rads to the adult thyroid. It is not being postulated here that persons normally lick over a square meter of surface, but it illustrates the very heavy contamination that might exist in the environment, and that prevention of entry of significant amounts into the body would be a serious consideration.

6. Based on radiological decay only, it would require about 80 days for the I^{131} activity to decay by a factor of 1000. Even considering weathering effects it is doubtful if pasture lands would be useable by then, since doses in the order of a few hundred rads to the infant's thyroid may be carcinogenic.(8)

Thyroid Dose From Continuous Intake of I^{131} at a Daily Rate Decreasing Proportionally to the Radiological Decay

Assumptions

1. An infant will drink 1000 milliliters of milk per day from the same source.

2. The mass of the infant's thyroid is two grams.

3. Thirty percent of the ingested I^{131} will be deposited in the thyroid. (This is on the low side. Studies have shown twice this value for some children).(9)

4. The thyroid is uniformly irradiated. (Some areas may receive higher than this "average" dose).

Step 1. Calculate the initial dose rate to produce 1.0 rad total dose to the thyroid.

$$D = \frac{R_o}{(\lambda_r)\ (\lambda_r + \lambda_b)}$$

where D = total dose

R_c = initial dose rate

λ_r = radiological decay constant

λ_b = biological decay constant

$$1 = \frac{R_o}{(8.66 \times 10^{-2})\ (8.66 \times 10^{-2} + 3.85 \times 10^{-3})}$$

$R_o = 7.8 \times 10^{-3}$ rads/day

Step 2. Calculate the uptake of I^{131} by thyroid to produce 7.8×10^{-3} rads/day

$$\frac{x\ (\mu c)\ (2.2 \times 10^6 \times 60 \times 24)\ (d/day/\mu c)\ (0.22)\ (Mev)\ (1.6 \times 10^{-6})\ (ergs)\ (Mev)}{100\ (ergs/gm/rad)\ (2)\ (gms)} = 7.8 \times 10^{-3} \text{ rads/day}$$

$x = 1.4 \times 10^{-3}\ \mu c$

Step 3. Calculate the concentration per liter to result in uptake of 1.4×10^{-3} μc to the thyroid.

(1.4×10^{-3}) $(3.3) = 4.6 \times 10^{-3}$ μc intake to body to result in one rad dose to thyroid

0.1 μc/1 = 22 rads (44 rads if 60% uptake is assumed)

<u>For the case of a single intake of I^{131}</u>

$$D = \frac{R_o}{(\lambda_r + \lambda_b)}$$

Thus, 0.1 μc/1 -----> 1.9 rads (3.8 rads if 60% uptake is assumed)

Gross Fission Products

1. Accompanying the ingestion of I^{131} would be the other radioisotopes found in mixed fission products. The beta emissions from these isotopes would irradiate the gastrointestinal tract. Based on unfractionated mixed fission products,* the radiation dose to the lower large intestine would be roughly a factor of two less than to the adult thyroid from I^{131} for intake during the first weeks after the fallout occurred. After this period the relative dose to the intestine from gross fission products would exceed that to the thyroid from I^{131}. The adult intestine is a much more radiosensitive organ than the thyroid, with 1000 - 2000 rad dose seriously threatening life.[10]

2. Very roughly -

a. At, say, one week after fallout occurred

$2\ KT/mi^2$ -----> $5 \times 10^4\ \mu c/ft^2$

b. Beta activity intake at one week to produce 1 rad to lower large intestine[11]

-----> $25\ \mu c$

c. Based on above figures -

If the activity from one square foot of surface were ingested, death would be imminent.

3. ~~Although this paper does not consider directly the effects on livestock, it will be realized that the doses from external gamma radiation in these areas of heavy fallout will essentially guarantee elimination of animals as a major source of food. A quantitative evaluation of the useability of~~

*This condition might be approached for surface contamination but would not hold for milk contamination due to the discriminatory effect in the cow.

D. Strontium-90

1. General.

$2\ KT/mi^2$ -----> 200 curies Sr^{90}/mi^2

Due to fractionation there may be 2 - 3 times less than this for the close-in areas, i.e. 67-100 curies Sr^{90}/mi^2

2. $80\ mc/mi^2$ -----> 8 S.U. in children (in equilibrium)* (17)

or $10\ mc/mi^2$ ----> 1 S.U. in children. This is based on U.S. diet including milk as a major source of calcium. Use of other foods as a source of calcium would increase the Sr^{90} intake due to less discriminatory factors.(18)

3. Using 200 curies Sr^{90}/mi^2 and conversion factor

$10\ mc/mi^2$ -----> 1 S.U. at equilibrium.

20,000 S.U. -----> 20 r/yr to bone marrow**

-----> 470 r in 35 years (assuming(a) mean life of surviving population in 35 years, and a radiological decay of Sr^{90} in environment and in man).***

4. The above estimates do not consider any decontamination measures, selection of lesser contaminated foods for consumption, or use of foods from lesser contaminated areas. One may assume these factors will reduce the above estimates by whatever degree we wish to postulate the effectiveness of the factors.

* Equilibrium in children might be reached in 2 - 3 years. Equilibrium would be approached in adults only after many years and to this extent calculations overestimate the effect.

** This may be a somewhat low estimate.

***The biologically available strontium would be expected to decrease naturally with time faster than its radiological decay would indicate, therefore, the assumption used here tends to overestimate the exposure.

Where: R_o = initial dose rate to bone marrow (20 r/yr).

t = time (years) after start of irradiation.

λ = radiological decay constant.

$$D_{r\text{ - yrs}} = \int_0^{35} R_o \; e^{-\lambda t} \left[35 - t \right] dt$$

$$D_{r\text{ - yrs}} = 35\, R_o \int_0^{35} e^{-\lambda t} \; dt - R_o \int_0^{35} t e^{-\lambda t} \, dt$$

$$= \frac{35\, R_o}{\lambda} \Big[e^{-\lambda t} \Big]_{35}^{0} - R_o \left[\frac{t e^{-\lambda t}}{\lambda} + \frac{e^{-\lambda t}}{\lambda^2} \right]_{35}^{0}$$

$$\cong 9{,}400 \text{ r - years}$$

E. Other Bone Seekers.

The two other principal bone seeking radioisotopes (strontium-89 and barium-140-lanthanum-140) are not included since they contribute such a relatively small additional dose when intake is considered over a period of time.

RELATIVE DOSES TO THE BONES FROM

STRONTIUM-90, STRONTIUM-89, BARIUM-140-LANTHANUM-140[a]

	Single Intake at D + 1 day			Continuour Intake from 1st day - 35 yrs.[c]
	Relative activity at D + 1 day	Relative dose rate to bone[b]	Relative total doses to bones[b]	Relative total doses to bones
Sr^{90}	1	1	1	1
Sr^{89}	180	100	1.9	0.018
Ba^{140}-La^{140}	1100	320	1.4	0.0033

(a) No fractionation assumed.

(b) Considering relative half-lives, energies and percent uptake to the bones.

(c) Assuming radiological decay of isotopes in the environment.

F. Cesium-137 (external)*

1. General.

$2\ KT/mi^2 \xrightarrow{\sim} 400$ curies Cs^{137}/mi^2

Due to fractionation this may be 2 - 3 times less for the close-in areas, i.e. 133 - 200 curies Cs^{137}/mi^2.

2. External exposure.

Roughly 1 megacurie $Cs^{137}/mi^2 \xrightarrow{\sim} 4r/hr$

$$R = (4 \times 10^{-4})\ (4) \longrightarrow 1.6 \times 10^{-3} r/hr$$

$$D_{35\ yr.} = \frac{38}{7.03 \times 10^{-5}} \left[1 - e^{-(7.03 \times 10^{-5})(365)(35)} \right]$$

$$= 3.20 \times 10^5 \text{ mr}$$

$$= 320 \text{ r per 35 years}$$

3. These calculations are based on an infinitely flat plane and no account is taken of weathering and shielding effects or of decontamination measures. Actual exposures might be as much as an order of magnitude less than the theoretical dose.(13) Based on similar calculations as for Sr^{90} irradiation of the bone marrow and a reduction factor of about 7** for shielding and weathering effects:

Leukemia ~ 0.13%

Bone Cancer ~ 0.03%

* Gamma dose from shorter lived isotopes is included in the section "External Gamma Exposure."

** To simplify calculations this factor is applied starting the first year although weathering effects would not be completed by then.

4. Internal exposure.

a. Intake of Cs^{137} is more a function of the rate of fall than total deposition. This is because Cs^{137} is very poorly absorbed from the soil and the intake is more a function of surface contamination than of foodstuff. Estimates of dose from internally deposited Cs^{137} is quite tenuous. Reference Thirteen suggests the relationship:

10 millicuries of $Cs^{137}/mi^2/yr$ -----> 0.5 - 2.0 mrem year.

Shortly after the attack some 400 curies of cesium-137 per square mile (assuming no fractionation) would fall in the area under consideration. This is a somewhat different situation than the one upon which the above relationship was based, inasmuch as this is a single fallout (the Cs^{137} dribble from the stratosphere and troposphere would contribute relatively little). However, additional dosage will come as the cesium is being eliminated from the body after reaching equilibrium with the intake. Also, with such a heavy contamination in the environment as postulated here, there will be some re-suspension of the cesium after deposition on the ground.

As great, or greater, an uncertainty would be the contribution of the shorter lived isotopes present in the fallout. Time has not permitted an analysis of this factor. Whereas, the theoretical external gamma dose from shorter lived isotopes may be 2-1/2 times that of Cs^{137} (see page 27 for further discussion), their absorption into the body is much less. In addition there undoubtedly are other gross fission products that are absorbed into the body yielding a beta whole body dose.

H. <u>Genetics</u>[a]

Assume doubling dose ----> 50 r [b] then,

A. Additional tangible defects

$\frac{670^{(c)}}{50} \times \frac{1}{10} \times 2\%$ --~--> 2.7% or less[b] of all live births first generation[d]

B. Additional stillbirths and childhood deaths

2-1/2 times tangible defects[19]

(2.5) (2.7%) --~--> 6.7% or less[b] of all pregnancies first generation[d]

C. Additional embryonic and neonatal deaths

5 times tangible defects[19]

(5) (2.7%) --~--> 14% or less[b] of all conceptions first generation[d]

(a) The following estimates generally apply to relatively large populations and therefore would not be so appropriate to the more limited numbers of persons being considered here.

(b) ~~Recent data from Dr. Russell (Oak Ridge) shows less production of genetic defects at lower dose rates by a factor of about four. The above estimates, therefore, may be high.~~

(c) Total genetic exposure.

(d) With decreasing effects in succeeding generations.

(e) Normal rates today -
2% (of all live births) - tangible defects
5% (of all pregnancies) - stillbirths and early childhood deaths
10% (of all conceptions) - embryonic and neonatal deaths

Carbon-14

1. Assume: 1 M.T. (total yield) $\dashrightarrow 2 \times 10^{26}$ neutrons (Outside bomb) $\dashrightarrow 4.7$ Kg C^{14}

   If one-half of neutrons "lost" to ground (i.e. surface bursts),

   then $\dashrightarrow$ 2.4 kg. C^{14}/M.T.

2. 3953 M.T. (total yield) $\overset{\sim}{\dashrightarrow}$ 9.3×10^3 kg. C^{14}

3. There are two reservoirs for freshly produced C^{14}:(21)

   4.4% in reservoir A[a] with Tm of 8070 yrs.

   95.6% in reservoir A with Tm of 27.2 yrs.

4. There are 3200 kg. C^{14} normally present in reservoir A[b].

$$\frac{(9.3 \times 10^3)\ (4.4 \times 10^{-2})}{3200} \times 8070 \times 1.5^{(c)} = 1550 \text{ mr}$$

$$\frac{(9.3 \times 10^3)\ (9.6 \times 10^{-1})}{3200} \times 27.5 \times 1.5 = \underline{120 \text{ mr}}$$

Total 1670 mr or $\sim$1.7r

5. Assuming that transmutations account for roughly the same number of genetic defects as does radiation, (22) then: $\sim$3.4 r "effective" over 8000 years.

6. During the same period of time (8000 years) the dose from naturally occurring radioisotopes in the environment and from cosmic rays might amount to 800 r (assuming no change in the present rate). The effect from C^{14} would not be zero but would not constitute a problem to the same degree as other factors.

(a) The atmosphere, the land biosphere, and humus.

(b) This assumes uniform distribution over the world which may not be too greatly in error for C^{14}.

(c) Yearly dose from C^{14} present in environment.

REFERENCES

1. The Effects of Nuclear Weapons. June 1957. Prepared by the Department of Defense, published by U.S. Atomic Energy Commission. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.

2. Ionization Rate and Photon Pulse Decay of Fission Products From The Slow-Neutron Fission of U-235, Miller, C. F. and Loeb, P. U.S. Naval Radiological Defense Laboratory, San Francisco 24, Cal. August 1958.

3. A Review of Information on the Gamma Energy Radiation Rate from Fission Products and its Significance for Studies of Radioactive Fallout. Knapp, Harold A., Statement before the Joint Atomic Energy Committee, Hearings on Fallout, 1959.

4. "Local Fallout Radioactivity", Lapp, Ralph E., Bulletin of Atomic Scientists, Vol. XV, No. 5, May 1959.

5. An Assessment of Hazards Resulting From The Ingestion of Fallout by Grazing Animals. Russell, R. Scott, Martin, R. P., and Wortley, G. ARC/RBC/5 AERE, Harwell 9-17-56.

6. "Radioactivity in Thyroid Glands Following Nuclear Weapons Tests," Van Middlesworth, L. Science, June 1, 1956, Vol. 123, No. 3205.

7. "Two Ways to Estimate Thyroid Dose From Fallout". Dunning, G. M. Nucleonics, Feb. 1956, Vol. 14, No. 2.

8. Pathologic Effects of Atomic Radiation. National Academy of Sciences - National Research Council, 1956. Washington, D. C.

9. "Radioactive Iodide Uptake of Normal Newborn Infants", Van Middlesworth, L. A.M.A., American Journal of Diseases of Children, Vol. 88, Oct. 1954.

10. "Some Effects of Ionizing Radiation on the Physiology of the Gastro-intestinal Tract." A Review. Lecture and Review Series No. 56-2. Conard, Robert, Naval Medical Research Institute, Bethesda, Maryland, March 1956.

11. "Criteria for Establishing Short Term Permissible Ingestion of Fallout Material". Dunning, G. M. American Industrial Hygiene Journal, April 1958, Vol. 19, No. 2.

12. Civil Defense in Western Europe and the Soviet Union. Fifth Report on Committee on Government Operations. April 27, 1959. U. S. Government Printing Office. (Soviet Union was ahead of west with civil defense!)

13. Report of the United Nations Scientific Committee on the Effects of Atomic Radiation. Supplement No. 17 (A/3838). New York, 1958, p. 170.

14. Leukemogenic Effects of Radiation, Law, Dr. Lloyd W., Head, Leukemia Studies Section, National Cancer Institute, U. S. Public Health Service, before the Joint Congressional Committee on Atomic Energy, Hearings on Fallout, May 1959.

15. Radiation Induced Life Shortening and Associated Effects. Statement by Dr. Douglas Grahn before Joint Congressional Committee on Atomic Energy, Hearings on Fallout, May 1959.

16. "A Survey of Childhood Malignancies", Stewart, Alice, J. Webb and D. Hewitt, British Medical Journal, Vol. I, June 28, 1958.

17. Statement of 1959 Fallout Prediction Panel to Joint Committee on Atomic Energy. Ad Hoc Committee.

18. Statement of Dr. C. L. Comar, Cornell University, before the Joint Congressional Committee on Atomic Energy, Hearings on Fallout, May 1959.

19. Personal communication. Dr. Henry Blair, University of Rochester.

20. J. F. Crow, Report of the Congress of the United States, Joint Committee on Atomic Energy, Special Subcommittee on Radiation: Hearings on the Nature of Radioactive Fallout and its Effect on Man (Government Printing Office, Washington, D.C., 1957).

21. "Genetic and Somatic Effects of Carbon-14." Pauling, L. Science Nov. 14, 1958, Vol. 148, No. 3333.

22. Private communication. Dr. Lester Machta, U. S. Weather Bureau.

23. The Biological Hazard to Man of Carbon-14 from Nuclear Weapons. Totter, John R., M. R. Zelle and H. Hollister (WASH-1008) Technical Information Services Extension, Oak Ridge, Tennessee.

Reprinted from AMERICAN INDUSTRIAL HYGIENE ASSOCIATION JOURNAL
Volume 19, No. 2, April, 1958
Printed in U.S.A.

Criteria for Establishing Short Term Permissible Ingestion of Fallout Material

GORDON M. DUNNING

Division of Biology and Medicine Atomic Energy Commission, Washington, D. C.

THE CRITERIA for establishing permissible ingestion of radioactive fallout material under emergency conditions for several weeks following a nuclear detonation are dependent primarily on exposures to the,

a. gastrointestinal tract from the gross fission product activity,

b. thyroid from the isotopes of iodine and,

c. bone, principally from Sr^{90}-Y^{90}, Sr^{89}, Ba^{140}-La^{140}.

I. Doses to the Gastrointestinal Tract

The following principal assumptions are used in calculating the doses to the gastrointestinal tract of adults:

a. The calculations are based on the methods contained in reference one.

b. The fallout material is 90 per cent insoluble. (See IV. Discussion below).

c. The activity decays according to the principle of $(\text{time})^{-1.2}$.

d. The energy delivered is all derived from the beta emissions, having a mean energy of 0.4 Mev when in the lower large intestine. (See Graph 1)[2]

e. The total daily consumption of food and water is 2200 grams or milliliters.

The method of calculation is according to the following equation:

$$\frac{\text{(Total number of disintegrations occurring in organ) (Energy of emissions) } (8.0 \times 10^{-9})}{\text{Mass of Organ}} = \text{Dose (rads)} \quad (1)^*$$

The number of disintegrations taking place in the organ may be calculated according to equation two:

$$\text{Total number of disintegrations} = 5A_a\, t_a^{1.2}[t_a^{-0.2} - t_b^{-0.2}] \quad (2)$$

Where: A_a = number of disintegrations per unit time at time "a" after detonation.
t_a = time "a" after detonation.
t_b = time "b" later than "a".

One of the more useful forms for the criteria would be in units of permissible concentrations at time of intake. This will somewhat complicate the calculations since there will be a decrease in activity as the material passes along the gastrointestinal tract. When such calculations are made according to the above assumptions and equations, it may be seen that the critical organ is the lower large intestine except for the first hours immediately following the detonation. (Table I shows the relative doses to parts of the gastrointestinal tract as a function of time.) Therefore, Graph 2 is based on the activity at time of ingestion to produce one rad of dose to the lower intestine.

For example, Graph 2 shows that if about 48 microcuries are ingested on the 24th hour after detonation, the lower large intestine may receive one rad of radiation dose. This was calculated in the following manner.

Step 1. Determine the total number of disintegrations in the lower large intestine necessary to produce 1.0 rad.

From equation (1)

$$\frac{\text{(Number of disintegrations) (0.4) } 8.0 \times 10^{-9}}{150} = 1$$

Number of disintegrations = 4.7×10^{10}

Step 2. Determine the activity at time of intake to produce 4.7×10^{10} disintegrations within the large intestine.

$$\frac{4.7 \times 10^{10}}{0.9} = 5.2 \times 10^{10}$$ disintegrations intake required (assuming 10% solubility).

From equation (2)

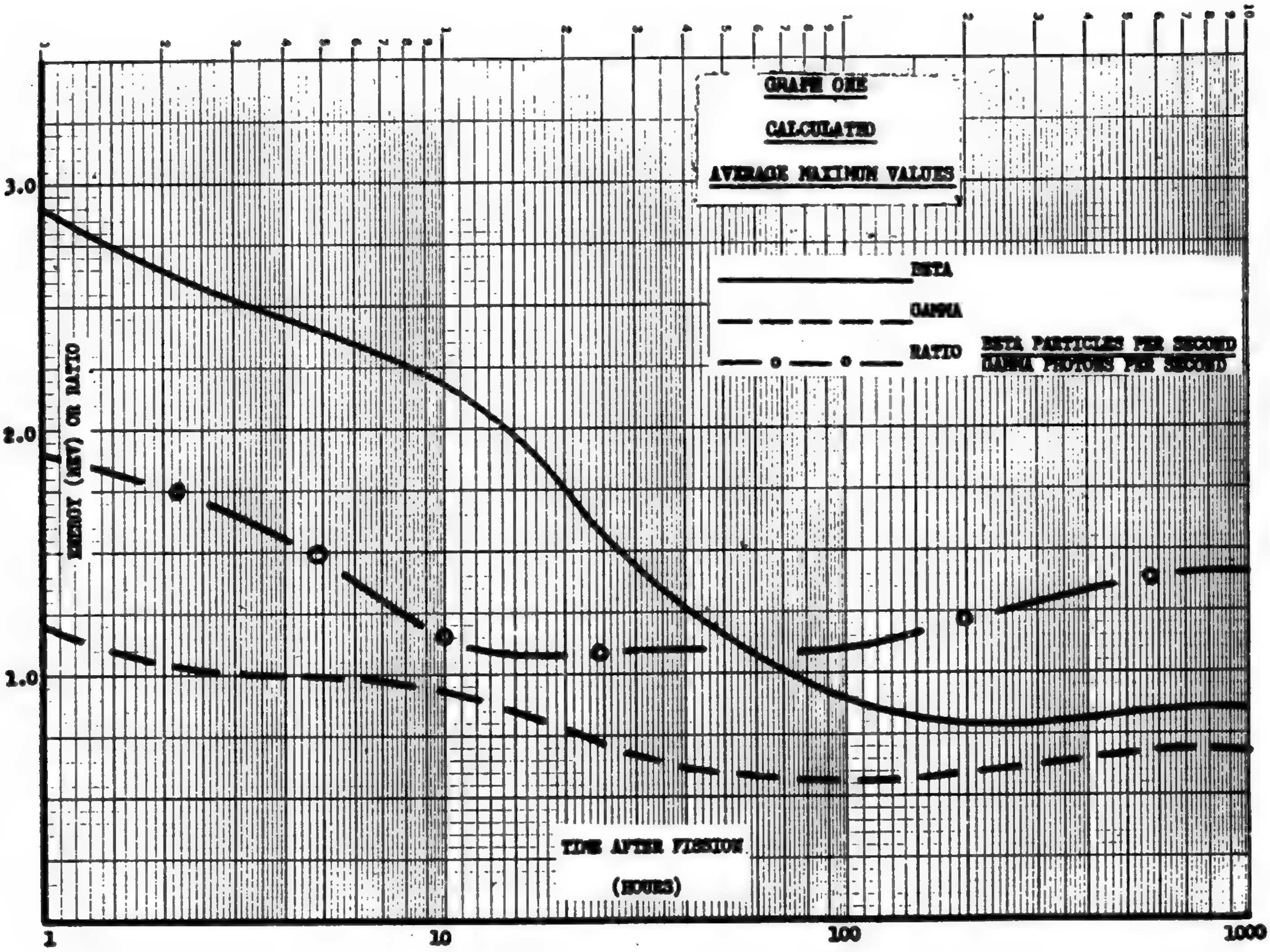
$$5.2 \times 10^{10} = (5)\ (A_{37})\ (37^{1.2})\ [37^{-0.2} - 55^{-0.2}]\ *$$

$A_{37} \cong 3.7 \times 10^9$ d/hr.
$A_{24} \cong 6.2 \times 10^9$ d/hr.
$A_{24} \cong 47\ \mu c$

* The rad is the unit of absorbed dose equal to 100 ergs per gram.

$$\frac{1.6 \times 10^{-6}\ \text{(ergs/Mev)}\ 0.5\ \text{(proportion of total energy to gastrointestinal tract)}}{100\ \text{(ergs/gm-rad)}} = 8.0 \times 10^{-9}$$

* If the time of intake is the 24th hour, then the start of irradiation of the lower intestine is 24 + 13 = 37th hour, according to reference one.



GRAPH 1

TABLE I

Relative Doses to Gastrointestinal Tract from Ingestion of Fallout Material

	Time After Detonation That Ingestion Occurs		
	1st Hour	1st Day	Limiting Case*
Lower Large Intestine	1.0	1.0	1.0
Upper Large Intestine	1.3	0.71	0.49
Small Intestine	0.26	0.054	0.03
Stomach	0.86	0.063	0.03

* Based on assumption that there is no significant decrease in activity during time of passage through gastrointestinal tract. After a week following detonation the decrease in activity between the stomach and the midpoint of time in lower large intestine is within about 20% of this condition.

Graph 2 has been used in estimating radiation doses to the lower large intestine for prolonged periods of ingestion (Table II). The following calculations are illustrative for the period of 24th to the 120th hour (start of intake at the beginning of the 2nd day after detonation for a duration of four days).

Step 1. Determine the number of microcuries at time of ingestion to produce 1.0 rad to the lower large intestine.

From Graph 2 take the mid point of intake period (72nd hour) $\rightarrow$ 31 μc. (This is obviously an approximation since the exact times of intake during the four-day period will be unknown.)

Step 2. Determine the activity at time of intake.

From equation (2)

$31 = 5A_{24}\ 24^{1.2}\ [24^{-0.2} - 120^{-0.2}]$

$A_{24} \cong 0.94\ \mu c/hr$

Since there is assumed a 2200 ml/day intake

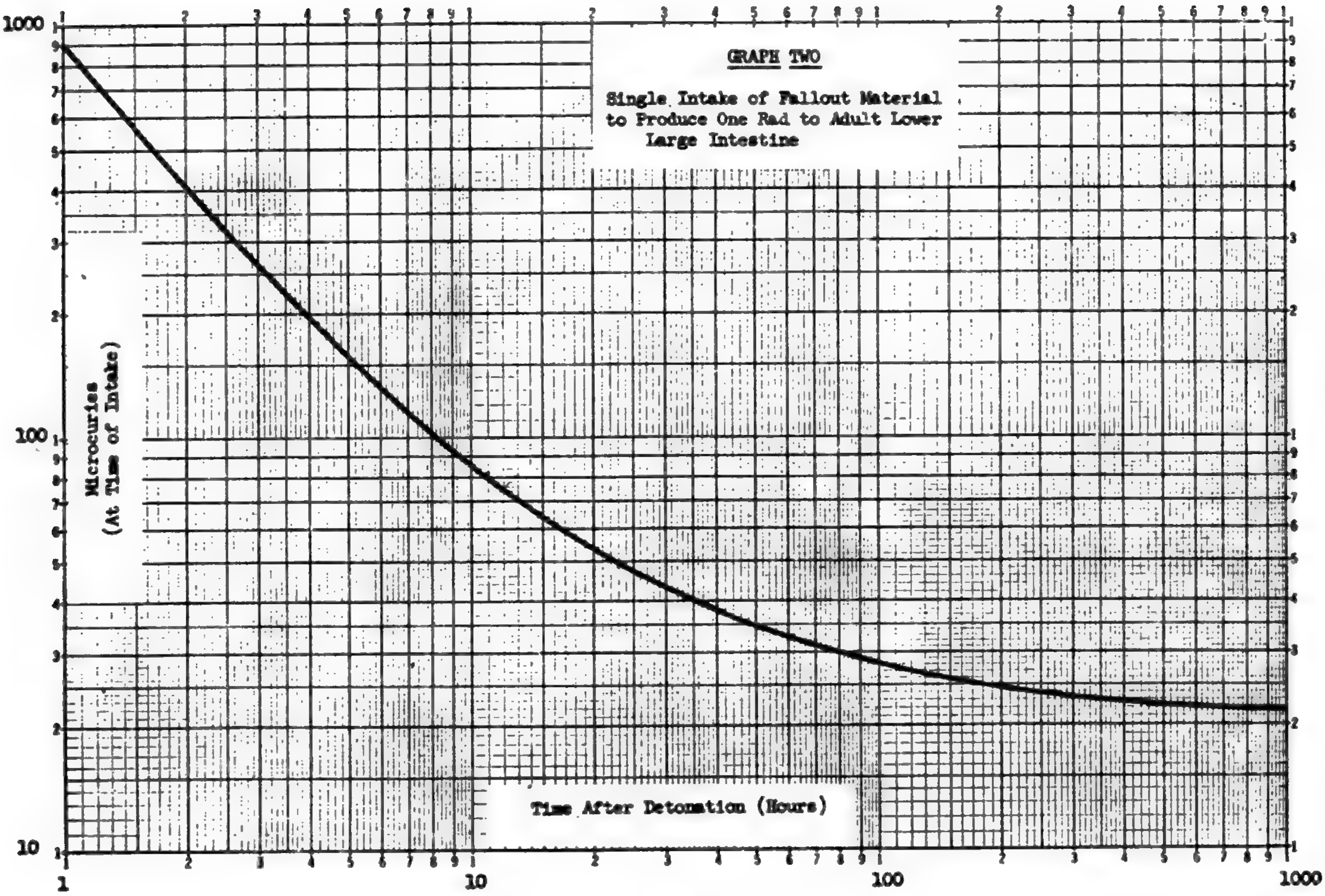
$$0.94 \times \frac{24}{2200} \cong 0.010\ \mu c/ml \text{ or gm}$$

II. Doses to the Thyroid

The following principal assumptions are used in calculating the doses to the adult thyroid from intake of activity from fallout material:

a. The percentages of the isotopes of iodine in mixed fission products are according to Hunter and Ballou.[3]

b. Twenty percent of the ingested I^{131} reaches the thyroid.



GRAPH 2

c. The mean energy is 0.22 Mev.

d. The thyroid weight is 20 grams. (See IV. Discussion below)

e. The percentages of shorter-lived isotopes of iodine that reach the thyroid and their doses are according to reference four.

The method of calculation of doses to the thyroid is illustrated by computing that amount of intake of fission products at the 48th hour to produce 1.0 rad.

Step 1. Determine the dose rate on the day of intake of I^{131} to produce 1.0 rad to the thyroid.

$D = (R/\lambda_e)$

Where: D = dose (1.0 rad)

R = dose rate on initial day

λ_e = effective decay constant (radiological and biological)

$1.0 = (R/0.09)$

$R = 0.09$ rads/day

Step 2. Determine the number of microcuries of I^{131} to produce 0.09 rad/day

$$\frac{X(\mu c)(2.2 \times 10^6)(60 \times 24)(1.6 \times 10^{-6})(0.22)}{(100)(20)} = 0.09$$

$X = 0.16$ μc to thyroid or

(0.16) $(5) = 0.80$ μc I^{131} ingested

Step 3. Determine relative doses from I^{131} and I^{short} according to Graph 3.[4]

TABLE II

Approximate Fission Product Activities (Microcuries per Milliliter of Gram $\times$ 10^2) to Produce one Rad Dose to Lower Large Intestine*

Duration of Ingestion (Days)	Start of Intake (Days after detonation)							
	1 (1st Hour)	2 (24th Hour)	3	4	5	10	15	20
1	35	2.5	1.9	1.7	1.4	1.1	1.1	1.0
2	24	1.7	1.1	0.89	0.81	0.62	0.57	0.53
3	15	1.3	0.82	0.65	0.56	0.41	0.40	0.37
4	13	1.0	0.65	0.53	0.46	0.33	0.30	0.29
5	12	0.9	0.57	0.44	0.39	0.28	0.25	0.22
10	9.2	0.64	0.40	0.29	0.25	0.17	0.14	0.13
15	7.8	0.53	0.33	0.26	0.21	0.13	0.11	0.097
20	7.5	0.49	0.29	0.21	0.18	0.11	0.089	0.079

* a. Activities computed at start of intake period.

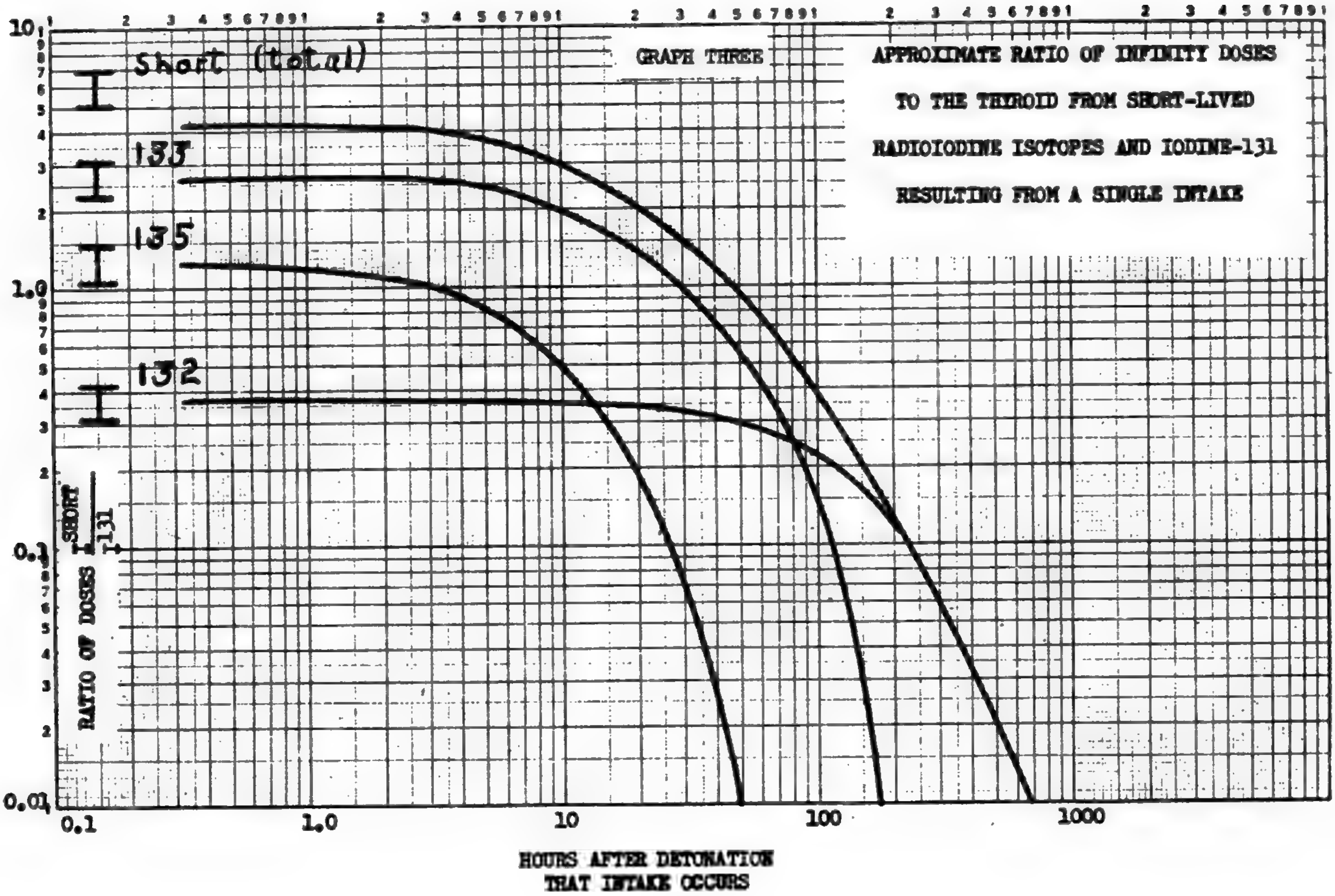
b. Based on intake of 2200 milliliters or grams of water and food per day for adults.

At 48th hour, the relative contribution to total dose from I^{131} and I^{short} is about 1/1.

Therefore, ingestion of 0.4 μc I^{131} (equivalent) at 48th hour will produce 1.0 rads to thyroid.

Step 4. Determine the number of microcuries of fission products required to yield the required I^{131} activity. At 48th hour, I^{131} constitutes about 2.35% of total activity. Therefore,

$(0.4/0.023) \cong 17$ μc of fission products.



GRAPH 3

Graph 4 shows the number of microcuries of fission products ingested at times after detonation to produce 1.0 rad to the thyroid.

III. Doses to the Bones

The three principal bone-seeking isotopes of concern are Sr^{90}-Y^{90}, Sr^{89}, and Ba^{140}-La^{140}. Evaluation of these may be made in terms of amount deposited in the bones versus maximum permissible body burdens, or in rads of dose that they deliver after deposition. Since values for maximum permissible body burdens are based on the concept that these will be maintained indefinitely in the body, they are not so valid for Sr^{89} and Ba^{140}-La^{140} when considering short periods of emergency intake.

The following principal assumptions are used in calculating the doses to the bones of adults:

a. The percentages of the isotopes of Sr^{90}-Y^{90}, Sr^{89}, and Ba^{140}-La^{140} in mixed fission products are according to Hunter and Ballou.[3]

b. The percentages of intake of these isotopes that are deposited in the bones, the energies of emissions, and their effective half lives are according to reference five—except for Sr^{90} where a 27.7 year radiological half life is used here.

c. The mass of the bones is 7,000 grams.

The method of calculation of doses to the bones is illustrated by computing the dose from Sr^{89} from the intake of 27 microcuries (See IV Discussion below) of mixed fission products on the 120th hour. Similar calculations were made for Sr^{90}-Y^{90} and Ba^{140}-La^{140} and then the three doses were added for each intake of fallout material.

Step 1. Determine the Sr^{89} to reach the bone.

According to reference 4:

The Sr^{89} content in mixed fission products on the 120th hour is 1.6%.

According to reference 5:

The intake of Sr^{89} to reach to the bones is 25%.

Therefore:

(27) (0.016) (0.25) = 0.108, to the bone.

Step 2. Determine the dose rate to the bones.

With an assumed effective energy of 0.55 Mev (reference 5):

$$\frac{(0.108)(2.2 \times 10^6)(60 \times 24)(1.6 \times 10^6)(0.55)}{(100)(7{,}000)}$$

$$= 4.3 \times 10^{-4} \text{ rads/day } \textit{or} \text{ 0.43 millirads/day}$$

Step 3. Determine total dose.

D total = $(R/\lambda e)$

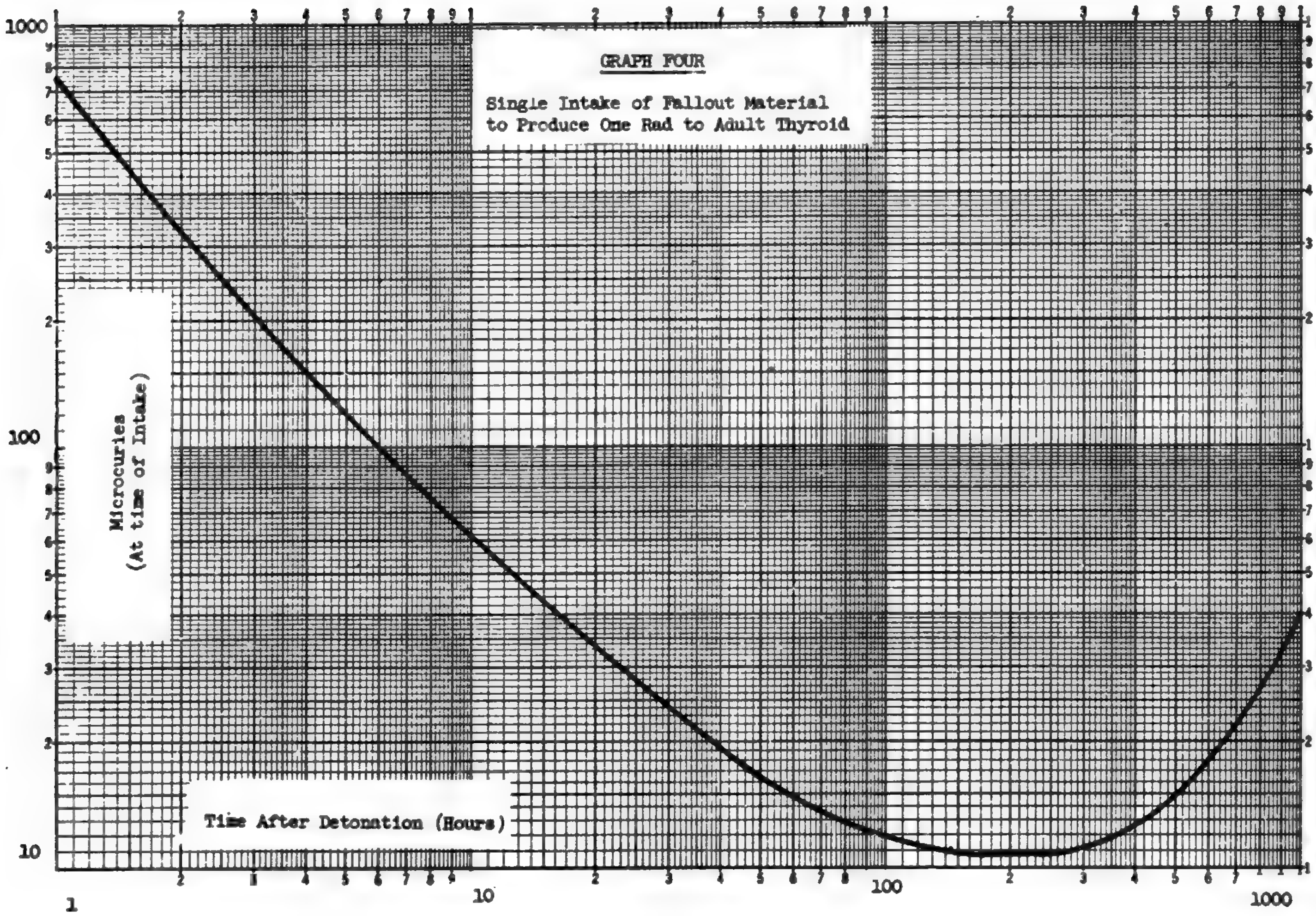
where: R = initial dose rate

λe = effective decay constant

D total = $(0.43/0.0133) \cong 32$ millirads*

* The relative total doses from these isotopes are as follows:

Time of intake	Sr^{90}	Sr^{89}	Ba^{140} — La^{140}
24th hour	0.6	1.00	0.6
20th day	1.00	1.00	0.3



GRAPH 4

IV. Discussion

A. Solubility

The solubility of fallout material varies, depending among other factors upon the surface over which the detonation occurred. The fallout material collected in soil samples at the Nevada Test Site has been quite insoluble, i.e. only a few per cent in distilled water and roughly 20–30 per cent in 0.1 N HCl. However, it would be expected that the activity actually present in drinking water supplies would be principally in soluble form. The water collected from a well and a cistern on the Island of Rongelap (Table III) about 21 months after the March 1, 1954 fallout, was found to have about 80 per cent of the activity in the filtrate, but there was an undetermined amount that settled to the bottom. Other data suggest the material to have been about 10–20 per cent soluble in water.

In the event contaminated food is ingested it is possible that the total activity—soluble and insoluble—may find its way into the gastrointestinal tract since at times immediately following a fallout most of this activity probably would come from the surface contamination rather than the soil-plant-animal cycle. There may then follow some solubilizing in the acid stomach with subsequent removal from the tract before reaching the lower large intestine.

TABLE III

Concentrations in Water on Islands in the Pacific and Estimated Gamma Dose Rates at D + 1, Three Feet Above Ground

Date	Location	Gross Fission Product Activity (*d/m*/ml)
	Rongelap Island (3.5 roentgens per hour)	
D + 2	Cistern	~50,000–75,000
D + 34	"	~5,500
D + 34	Openwell	~2,000
D + 300	Cistern	~3
D + 330	"	~4
D + 600	"	~5.5
D + 600	Openwell	~0.5
D + 600	Cistern (With collapsed roof)	~1.3
	Kabelle Island (19 roentgens per hour)	
D + 330	Ground water	~48
	Eniwetok Island (8.5 roentgens per hour)	
D + 330	Cistern	~25
	Enibuk Island (1.3 roentgens per hour)	
D + 600	Standing water from can, drum, etc.	~1.4

It is assumed for these calculations that (a) 90% of the fallout material is insoluble when computing doses to the gastrointestinal tract, and (b) that the isotopes of iodine, strontium, and barium are all soluble when computing doses to the thyroid and to the bones. These assumptions are probably conservative, i.e. they may overestimate somewhat the radiation exposures.

B. Biological Significance

After the estimation of radiation doses by any procedure the final step is an evaluation in terms of biological effects both for short and long terms.

1. Gastrointestinal Tract

There have been few experiments where the gastrointestinal tract has been exposed in a manner similar to the one assumed here. One experiment[6] indicates lower doses to the intestine than the model proposed in reference 1.

In another experiment,[7] rats were fed 1.0 to 6.0 millicuries of yttrium-90 in a single feeding. Four of the 33 animals died of adenocarcinoma of the colon and additional animals died with acute and chronic ulceration of the colon. A second group of rats was given 0.46, 0.20, or 0.06 mc of Y^{91} per feeding over a period of three months with total accumulated amounts of 31.2, 15.6 and 4.68 mc respectively. Six of the eight animals at the two higher levels died with carcinoma of the colon and no malignancies were observed at the lowest level. The authors made no estimate of radiation doses.

In another experiment,[8] rats were kept alive by the use of parabiosis or para-aminopropriophenone either pre or post whole-body irradiation of 700–1000 roentgens. Four of the 21 rats developed tumors along the gastrointestinal tract (one each jejunum, ileum, duodenum, and colon), with four additional animals showing tumors in other organs. However, in comparing gastrointestinal versus whole-body irradiation, the question has been raised as to a possible indirect carcinogenic action in the latter case.[9] By using fast neutrons, lesser doses have been shown to produce an appreciable percentage of intestinal carcinomas in mice, but this is not so relevant to the present discussion of beta exposure.[10]

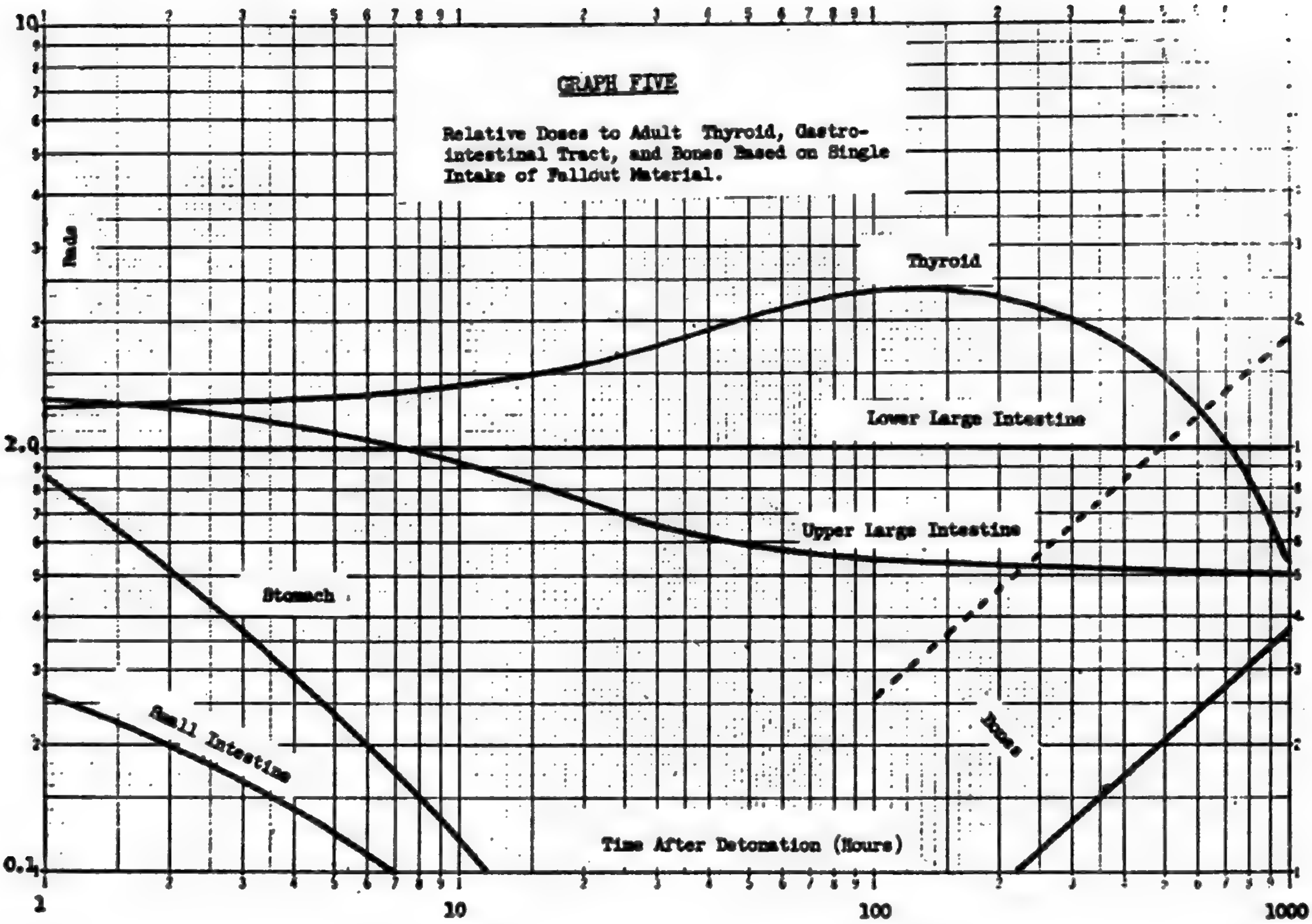
One summarizing statement of the short-term effects stated, "...though the gastrointestinal tract is one of the sensitive systems to ionizing radiation, it also has a most remarkable regenerative and reparative capacity. It takes doses of well over a thousand roentgens to damage the gut permanently in most mammals studied, and it is capable of rapid, dramatic recovery of anatomical and functional integrity with doses in the lethal range."[11] Evaluating the data from dogs exposed to whole-body X-radiation the authors said, "...it is suggested that doses of approximately 1,100 to 1,500 r may represent the upper limit of the possible efficacy of supportive measures in the treatment of the syndrome of acute radiation injury. With greater doses the damage to the intestinal mucosa appears irreparable and of an extent incompatible with life."[12] At the same time, it has been repeatedly indicated that the irradiation of the gastrointestinal tract plays a major role in gross whole-body effects associated with radiation syndrome.[11, 12, 13, 14, 15, 16, 17, 18, 19, 20] In fact one author[13] summarizes several experimental findings, "In producing acute intestinal radiation death, irradiation of any major portion of the exteriorized small intestine alone is almost equivalent to whole-body irradiation ...."

Graph 5 suggests the relative doses to the parts of the gastrointestinal tract, from ingestion of fallout material. The available experimental data does not permit a conclusive statement as to whole-body effects to be expected from such ratios of exposures. Most of these experiments are related to the criterion of death, but they do suggest that the major contributory factor to such effects such as nausea and vomiting associated with whole-body exposures of 100–200 roentgens, may be the result of the gastrointestinal reaction. Possibly a few hundred rads to the lower large intestine together with the concomitant lesser exposures to the upper large intestine, the small intestine and the stomach (according to Graph 5) may be in the range where radiation sickness might occur.

2. Thyroid

The study and treatment of disorders of the thyroid gland with radioiodine has led to considerable information on doses and their effects to this organ. (Only a partial list of references is noted.)[21, 22, 23, 24, 25] Whereas these treatments have been principally with abnormal thyroids, much of the information may be extrapolated to normal thyroids for the purposes of this discussion. In addition there are other data based on normal thyroids in patients suffering such ailments as congestive heart failure.[26]

The picture clearly presented is that the adult human thyroid is relatively insensitive to radiation. For example, Freedberg, Kurland, and Herman,[26] report, "...Seven days after administration of 17 and 20 millicuries of I^{131}, which delivered 14,500 and 31,000 rep, respectively, to the thyroid gland, no histologic



GRAPH 5

changes were noted which could be attributed to I^{131}.... Fourteen and twenty-four days, respectively, after administration of 59 and 26 millicuries of I^{131}, marked central destruction of the thyroid gland was noted...." Since the first two patients expired seven days after administration of the I^{131} from pulmonary edema, it does not eliminate the possibility that the destructive changes might have appeared in the thyroid if these patients had survived. However, the evidence from other studies strongly indicates that if any pathological effects were to be noted in the thyroid after an exposure of some 10,000 reps they would be minimal. Likewise, the possibility of serious damage to other organs of the body, such as parathyroids and trachea which are simultaneously exposed to the I^{131} radiations, would be exceedingly small.

On long terms effects, two summarizing statements may be made. "No thyroid neoplasm was found which could be attributed to I^{131},"[26] after doses to normal thyroids running into many tens of thousands of reps and after periods of observation up to more than eight hundred days. "In a series of over 400 patients treated with radioactive iodine at the Massachusetts General Hospital during the past ten years no known carcinoma of the thyroid attributable to this agent has developed. Definite answers to the question of carcinoma formation must await prolonged observation of treated patients."[26] Here the average treatment dose of I^{131} was 10 millicuries and of I^{130} 25 millicuries.

However, significantly lesser doses may be carcinogenic in children.[27] "...It has been suggested that the human thyroid is less radiosensitive than other tissues, such as bone, since after many years of treatment of Graves' disease with radioactive iodine, no cases of resulting carcinoma have been reported. The customary dosages of I^{131} in such cases yield at least 4000 rep to the gland. On the other hand, carcinoma of the thyroid found in children and young adults has almost invariably been preceded by x-ray treatment to the upper part of the body, in amounts such as to yield as little as 200 r to the infant thyroid. It has been estimated that less than 3 per cent of such treated cases yield carcinoma; nevertheless, the data suggest that 200 r is a potentially carcinogenic dose to the infant thyroid. While the possibility exists that the carcinogenic action may be an indirect, hormonal one, it must still be recognized that this, like leukemia, is an instance of significant car-

cinogenesis by less than 1000 rep. It seems likely that the infant thyroid is unduly susceptible, but that the adult thyroid is not. . . ."[28]

Table II indicates the amount of ingested fission product activity to produce one rad dose to the lower large intestine and Graph 5 shows the relative doses to the gastrointestinal tract and the thyroid. It may be seen that ingestion of a given activity on the fourth and fifth days may result in nearly two and one-half times the dose to the thyroid as to the lower large intestine. For a continuous consumption of fallout material from the first hour to the 30th day the ratio of doses is about 1.7.

3. Bones

It is recognized that the intake and deposition of strontium-89 and 90 are intimately associated with the calcium in the diet. Whereas it has been assumed here that a fixed percentage of the strontium intake is deposited in the bones (reference 5). It is realized that this method involves uncertainties, as would the necessary assumptions to generalize for a wide variety of calcium—strontium ratios and intakes to cover multiple categories. In situations where doses to the bones appear to be the critical criterion (such as later times after detonation than considered here), it would be necessary to make a more precise evaluation.

Unequal distribution of isotopes in the bones has been observed. Thus, the dotted line in Graph 5 is included to suggest a possible larger dose to those regions.

Considerable data have been collected on radiation produced bone cancers. One summarizing statement that places this in proper perspective with the other factors discussed above is ". . . Visible changes in the skeleton have been reported only after hundreds of rep were accumulated and tumors only after 1,500 or more."[29] When one examines Graph 5 for relative doses, and reviews the data on doses versus effects to the gastrointestinal tract and possibly children's thyroids (Table IV), it would appear that exposure to the bones is not the critical factor for ingestion of fallout material under emergency conditions, for the first few weeks after detonation.

TABLE IV

Some Possible Biological Effects from Radiation Doses to Specific Organs*

Dose (Rads)	Gastrointestinal Tract	Thyroid	Bones
10,000		Minor changes in structure	
	Serious damage—survival threatened		Tumor production.
1,000	Tumor Production		
	Immediate effects such as nausea	Potential carcinogenic dose to few percent of children	Minor changes in structure
100			

* Lesser short term effects would be expected from the same doses distributed in time.

4. Summary of Biological Effects

Table IV summarizes some possible biological effects from radiation exposures. Due to inherent uncertainties in such analyses together with expected wide biological variances among individuals, Table IV is intended only to suggest a generalized picture of doses versus effects.

The physical calculations of radiation doses made above were for adults. For equal intakes of radioactivity, children probably would receive higher exposures due to the smaller organ masses, and in the case of bones a greater deposition would be expected. Also, there is the possibility of tumor production in the thyroids of some children at relatively low radiation exposures. It would appear wise therefore to establish lower limits of intake of radioactivity for children.

C. PERMISSIBLE INTAKE

The preceding discussion attempts to give estimates of radiation doses resulting from intake of fallout material, together with some possible biological effects. How much intake is actually permitted depends upon many factors including the essentialness of the food and water to sustaining life, and one's philosophy of acceptable biological risks and damage in the face of other possible hazards such as mass evacuation. Table II and Graph 5 give estimates of the amount of contamination in food and water to produce certain radiation doses to the critical organs. Table IV indicates possible biological effects from given doses. Using these references, command decisions may be made as to permitted intake of radioactivity.

Such evaluations as attempted here are necessary and valuable for planning purposes, but once the fallout occurs the emergency of the situation may preclude immediate analysis of the food and water supplies. Further, abstaining from ingestion of food and water because it

TABLE V
Mean Body Burden of Rongelapese

Radioisotopes	Estimated Activity at One Day (μc)
Sr^{89}	1.6–22
Ba^{140}	0.34–2.7
Rare earth group	1.2
I^{131} (in thyroid)	6.4–11.2
Ru^{103}	0.013
Ca^{45}	0.019
Fissile material	0.016 (μgm)

might be contaminated could not be continued indefinitely. Therefore, the following three common-sense rules are suggested:

1. Reduce the use of contaminated food and water to bare minimum until adequate monitoring can be done; use first any stored clear water and canned or covered foods; wash and scrub any contaminated foods and;

2. If the effects of lack of food and water become acute, then use whatever is available but in as limited quantities as possible. Whenever possible select what seems to be the least likely contaminated water and/or foodstuffs; and

3. Since it is especially desirable to restrict the intake of radioactivity in children, give them first preference for food and water having the lowest degree of contamination.

In an area of heavy fallout one matter to consider is the relative hazards from the external gamma exposure versus internal doses from ingestion of the material. (Inhalation is thought to contribute only relative minor doses under the conditions discussed here). The best evidence on this point is the fallout that occurred on the Rongelapese in March 1954. Those in the highest exposure group received 175 r whole-body external gamma exposure yet their body burdens of internal emitters were relatively low (Table V).[30] These and other data suggest that:

If the degree of contamination of an area is such that the external gamma exposure would permit normal and continuous occupancy after a fallout, the internal hazard would not deny it.

This is based on such reasonable assumptions of (a) about 50% reduction of gamma exposure from out-of-doors doses afforded by living a part of each day in normal family dwellings, (b) washing and/or scrubbing contaminated foods, and (c) excluding areas where relatively little fallout occurred, but into which may be transported highly contaminated food and/or water. After longer periods of time during which the gamma dose rates in an originally highly contaminated area have decreased to acceptable levels, it probably would be necessary to evaluate the residual contamination for the bone seeking radioisotopes, especially strontium-90.

References

1. *Maximum Permissible Concentration of Radioisotopes in Air and Water For Short Period Exposure.* Morgan, K. Z., Snyder, W. S., and Ford, M. R. International Conference on the Peaceful Uses of Atomic Energy, July 8, 1955, Paper A/Cong. 8/P/79.
2. USNRDL-394. *The Ratio of Lung Beta Dose to Whole Body During Given Intervals After Atomic Detonation.* (Confidential) Sondhaus, C. A., 1952.
3. *Simultaneous Slow Neutron Fission of U^{235} Atoms I. Individual and Total Rates of Decay of Fission Products.* Hunter, H. F. and Ballou, N. E., U. S. Naval Radiological Defense Laboratory, April 1949.
4. "Two Ways to Estimate Thyroid Dose From Radioiodine in Fallout," Dunning, Gordon M., *Nucleonics* Vol. 14, No. 2, February 1956.
5. *Maximum Permissible Amounts of Radioistotpes in the Human Body and Maximum Permissible Concentration in Air and Water.* Handbook 52, National Bureau of Standards, March 1953.
6. "Estimated Tissue Dose From Internally Administered Radioisotopes," Final Progress Report Dec. 1, 1956–Nov. 30, 1957. Comar, C. L., Nold, M. M. and Hayes, R. L. Medical Division, Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tennessee.
7. "Carcinoma of the Colon in Rats Following the Feeding of Radioactive Yttrium," Lisco, H., Brues, A. M., Finkel, M. P. and Grundhauser, W., *Cancer Research* 1947, Vol. 7 p. 721.
8. "Neoplasms in Rats Protected Against Lethal Doses of Irradiation by Parabiosis and Para-Aminoproprio-phenone," Brecher, G., Cronkite, E. P., Peers, J. H., *Journal of the National Cancer Institute,* August 1953, Vol. 14, No. 1, p. 159–167.
9. "Radiation as a Carcinogenic Agent," Brues, A. M. *Radiation Research,* November 1955, Vol. 3, no. 3, p. 272–280.
10. "Induction of Intestinal Carcinoma in the Mouse by Whole-Body Fast-Neutron Irradiation," Nowell, C., Cole, L. J., Ellis, M. E., *Cancer Research,* October 1956, Vol. 16 No. 9, p. 873–876.
11. *Some Effects of Ionizing Radiation on the Physiology of the Gastrointestinal Tract. A Review.* Lecture and Review Series No. 56-2. Conard, Robert, Naval Medical Research Institute, Bethesda, Maryland, March 1956.
12. "Lesions of the Alimentary Tract of Dogs Exposed to Whole Body X-Radiations of 300 to 3,000 R." Brecher, G., and Cronkite, E. P., *American Journal of Pathology,* 1951, Vol. 27, p. 676–677.
13. "The Nature of Intestinal Radiation Death," Quastler, H. *Radiation Research,* April 1956, Vol. 4, No. 4.
14. "Effects of Partial Shielding of Rat Intestine During X-Irradiation." Swift, M. N., Taketa, S. T., and Bond, V. P., *Federation Procedures,* 1954, Vol. 13, p. 523.
15. "Prevention of Intestinal Radiation Death by Removal of the Irradiated Intestine," Osborne, J. W., *Radiation Research,* June 1956, Vol. 4, No. 6.
16. "Sensitivity of Abdomen of Rat to X-irradiation", Bond, V. P., Swift, M. N., Allen, A. C. and Fischler, M. C., *American Journal of Physiology,* Vol. 161, 1950, p. 323–330.
17. "Acute Intestinal Radiation Death. Studies on Roentgen Death in Mice, III." Quastler, H., Lanzl, E. F., Keller, M. E. and Osborne, J. W., *American Journal of Physiology,* February 1951, Vol. 164, No. 2, p. 546–556.
18. "Observations on Gastrointestinal Function After X-Ray

and Thermal Column Exposures," Woodward, Kent T. and Rothermel, Samuel, *Radiation Research*, October 1956, Vol. 5, p. 441–449.
19. "Modification of Acute Intestinal Radiation Syndrome Through Shielding," Swift, M. N. and Taketa, S. T., *American Journal of Physiology*, April 1956 Vol. 185, No. 1, p. 85–91.
20. "Lethal Effects of Intragastric Irradiation in the Dog." Littman, A., Fox, B. W., Schoolman, H. M., and Ivy, A. C., *American Journal of Physiology*, 1953, p. 347–351.
21. "Radioiodine in the Study and Treatment of Thyroid Disease: A Review." Kelsey, M. P., Haines, S. F., Keating, F. R., *The Journal of Clinical Endocrinology*, Vol. 9, No. 2 February 1949, p. 171–210.
22. *Radioisotopes in Medicine*, Andrews, G. A., Brucer, M. and Anderson, E. (Editors), September 1953. Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Chapter 18-27.
23. "A Critical Analysis of the Quantitative I-131 Therapy of Thyrotoxicosis." Freeberg, A. S., Kurland, G. S., Chamovitz, D. L., Ureless, A. L. *Journal of Clinical Endocrinology*, Vol. 12 1952, p. 86–111.
24. "Functional and Histologic Effects of Therapeutic Doses of Radioactive Iodine on Thyroid of Man." Dobyns, B. M., Vickery, A. L., Maloot, F., and Chapman, E. *The Journal of Clinical Endocrinology and Metabolism*. Vol. 13 No. 5, May 1953, p. 564.
25. "Biological Hazards and Toxicity of Radioactive Isotopes", Brues, A. M., *The Journal of Clinical Investigation*. Nov. 1949, Vol. XXVIII, No. 6, p. 1286–1296.
26. "The Pathologic Effects of I-131 on the Normal Thyroid of Man". Freeberg, A. S., Kurland, G. S. and Blumgart, H. L., *The Journal of Clinical Endocrinology and Metabolism*, Vol. 12, 1952, p. 1315–1348.
27. "Association of Irradiation with Cancer of the Thyroid in Children and Adolescents," Clark, D. E., *The Journal of the American Medical Association*, Nov. 1955, Vol. 159, p. 1007–1009.
28. *Pathologic Effects of Atomic Radiation*. National Academy of Sciences—National Research Council, 1956, Washington, D. C.
29. *The Biological Effects of Atomic Radiation—Summary Reports*. National Academy of Sciences—National Research Council, 1956, Washington, D. C.
30. *Some Effects of Ionizing Radiation on Human Beings*. Cronkite, E. P., Bond, V. P., and Dunham, C. L. (Editors). Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

Acknowledgment

Acknowledgement is gratefully made for the kind asistance in reviewing the manuscript and offering many helpful suggestions: Dr. Charles L. Dunham, Director, Division of Biology and Medicine, AEC, Washington, D. C.; Dr. Forrest Western, Assistant Director Division of Biology and Medicine, AEC, Washington, D. C.; Dr. Karl Z. Morgan, Director, Health Physics Division, Oak Ridge National Laboratory; Dr. Victor P. Bond, Brookhaven National Laboratory; Dr. George V. LeRoy, Associate Dean, School of Medicine, The University of Chicago; Dr. C. L. Comar, Director, Laboratory of Radiation Biology, Department of Physiology, State Veterinarian College, Cornell University; Dr. Stanton H. Cohn, Head, Internal Toxicity Branch, U. S. Naval Radiological Defense Laboratory, San Francisco 24, California; Mr. Charles Sondhaus, University of California, Berkeley, California.

Representative HOLIFIELD. Dr. Stanton H. Cohn will present testimony on the evaluation of the hazards from inhaled radioactive fallout. Dr. Cohn is presently with the Medical Physics Division, Medical Research Center, Brookhaven National Laboratory. He is a member of the Subcommittee on Inhalation Hazards of the Pathological Effects of the Atomic Energy Radiation Committee of the National Academy of Sciences. He was a member of the U.S. Naval Medical Team which provided emergency medical treatment to the Marshallese accidentally exposed to fallout from operations in 1954. He studied the internal radioactive contamination of the exposed Marshallese. He was also a member of the AEC medical team which made the 5-year medical survey of the Marshall Islands in 1959 and studied the internal radioactive contamination by measuring body burdens of various fission products of 250 Marshallese using a whole body gamma scintillation counter. He participated in the direction of the study of the residual contamination of plants and animals of the Marshall Islands in two surveys in 1955 and 1956.

Dr. Cohn, we are happy to have you before us today and you may now proceed.

TESTIMONY OF DR. STANTON COHN,[1] BROOKHAVEN NATIONAL LABORATORY

Dr. COHN. An individual exposed to an atmosphere contaminated with airborne radioactive particles will be subjected to both external and internal radiation. This contaminated atmosphere, which would most likely be an area of local fallout produced by a nuclear detonation, would subject the individual to penetrating gamma and superficial beta radiation from the exterior. Particles which become internalized as a result of inhalation and/or ingestion would subject the internal tisues and organs primarily to beta radiation, and to a lesser extent, to gamma radiation. Unconsumed fissile material may, in addition, supply internal alpha radiation.

It is difficult to determine the exact degree to which radiation from external and internal sources contribute to the total radiation an individual receives. It is even more difficult, and in fact, rather arbitrary (as will be shown later) to separate the contributions deriv-

---

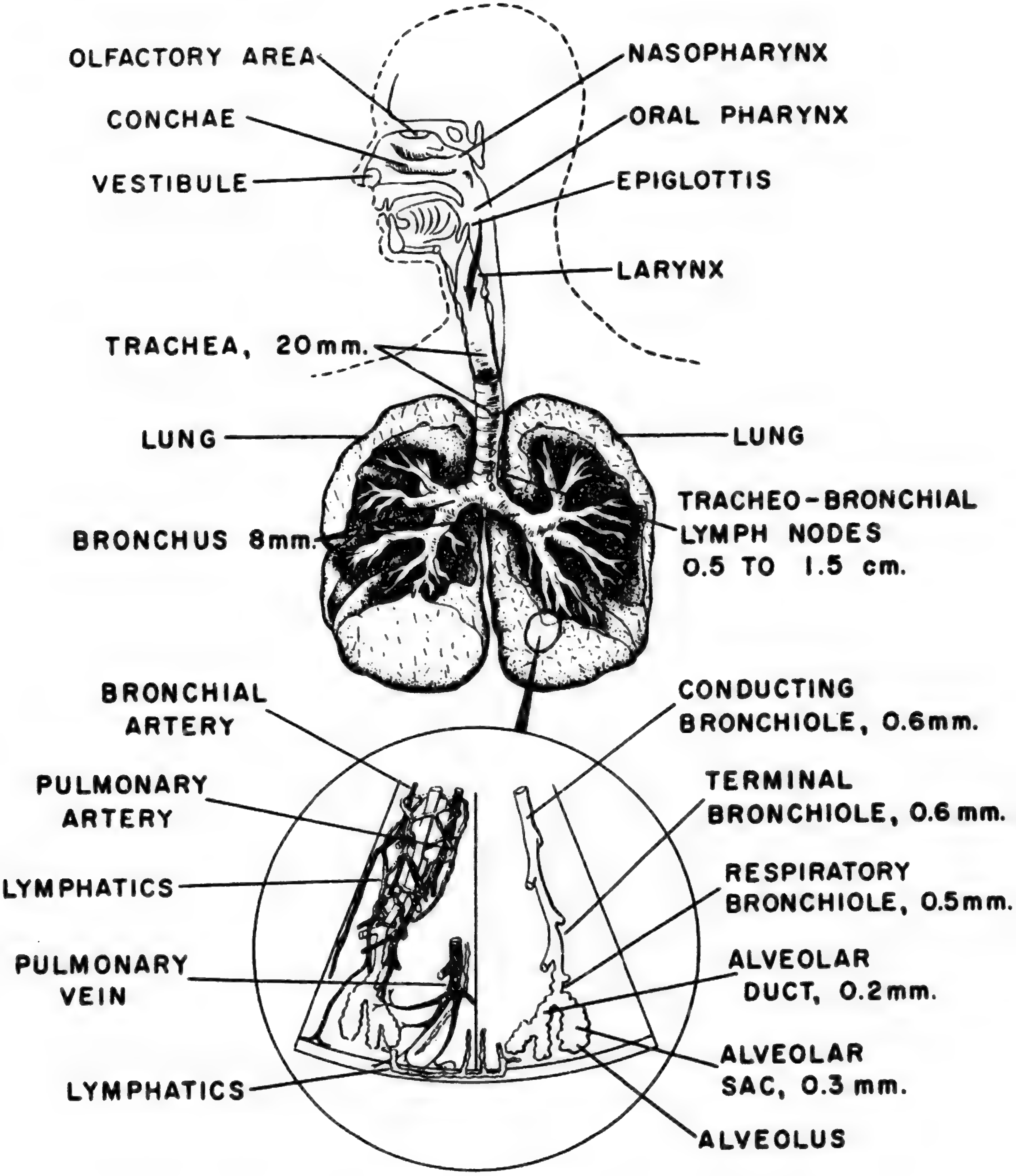
[1] I. Experience: Scientist, Medical Physics Division, 1958 to present, Medical Research Center, Brookhaven National Laboratory, Upton, Long Island, N.Y. Head, Internal Toxicity Branch, 1950–58, Biomedical Division, U.S. Naval Radiological Defense Laboratory, San Francisco, Calif. Research assistant, 1949–50, Crocker Radiation Laboratory, University of California, Berkeley, Calif. Biochemist, biomedical division, 1946–49, Argonne National Laboratory, University of Chicago, Chicago, Ill. Biochemist, laboratory of the 203d General Hospital, Paris, France, 1943–46, U.S. Army. Chemist, explosives, 1942–43, Kankakee Ordnance Works, Joliet, Ill., and Lake Ontario Ordnance Works, Niagara Falls, N.Y.

II. Education: University of California, Berkeley, Calif., 1952, Ph. D., physiology-radiobiology (Dr. Hardin Jones and Dr. D. H. Copp). University of Chicago, Chicago, Ill., 1949, S.M., physiology (Dr. Franklin McLean); 1946, S.B., Biochemistry.

III. Additional qualifications: Member of the Subcommittee on Inhalation Hazards of the Pathological Effects of Atomic Radiation Committee, National Academy of Sciences, 1956 to present. Member of the U.S. Navy medical team which provided emergency medical treatment for the Marshall Islanders accidentally exposed to fallout from Operation Castle, March 1954. Studied the internal radioactive contamination of the exposed Marshallese. Also member of the AEC medical team which made the 5-year medical survey of the Marshall Islands in 1959. Studied the internal radioactive contamination by measuring body burdens of 250 Marshallese using a whole body gamma scintillation counter. Participated in the direction of the study of the residual contamination of plants and animals of the Marshall Islands in two field surveys, 1955 and 1956. Member of the Advisory Committee on Civil Defense, 1958.

IV. Scientific Societies, memberships: Radiation Research Society, American Physiological Society.

THE RESPIRATORY TRACT

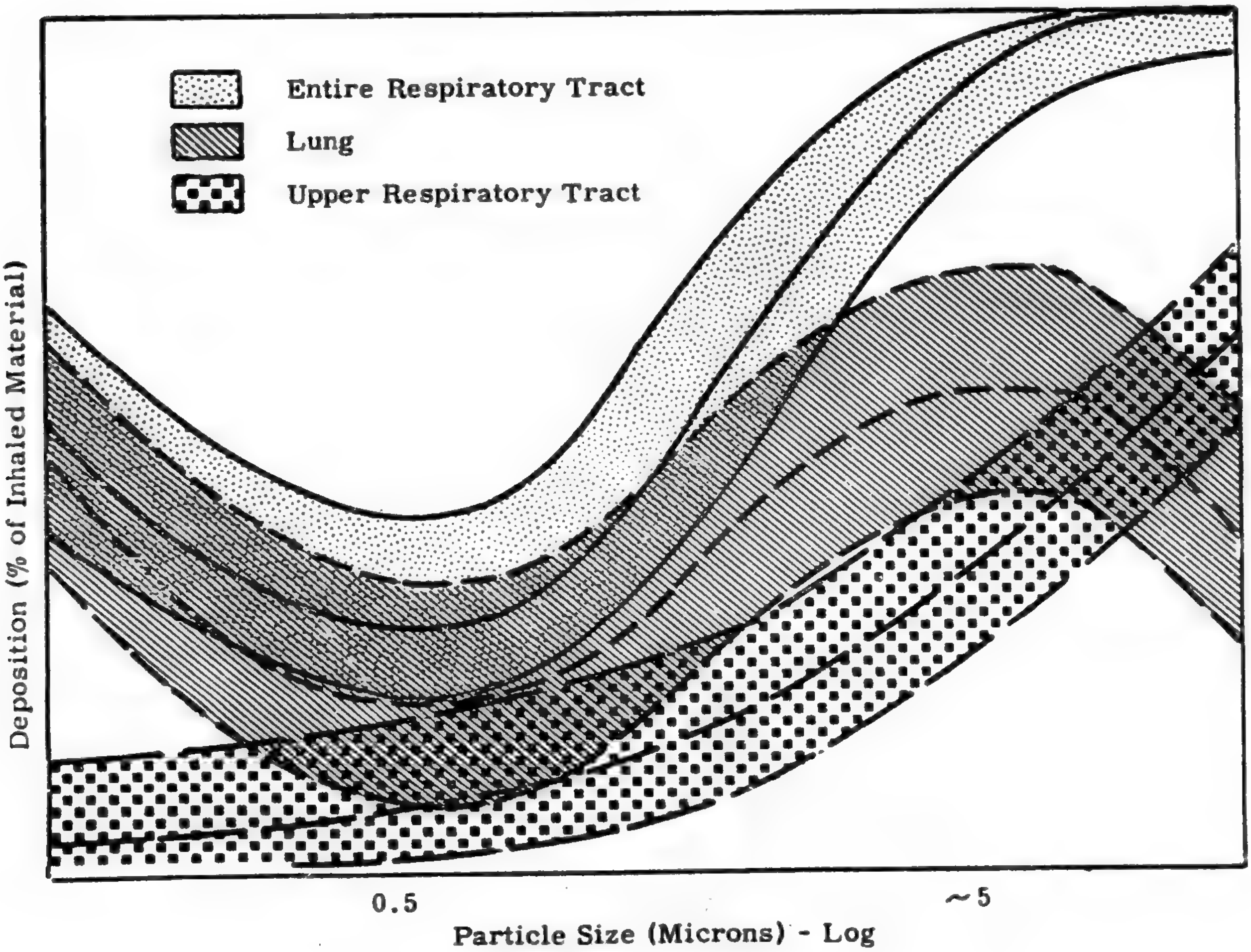


LUNG LOBULE

When inhaled fallout material enters the respiratory tract, a fraction of the material is retained. Some of this material is subsequently removed, but a portion may remain for an appreciable period. Probably the most important property of fallout which influences the fate of the particles in the respiratory system is the size of the particle.

Both experimental and theoretical data on the deposition of particles with respect to particle size are summarized in figure 2. For decreasing particle size, as would be expected, deposition occurs deepest in the lung. With the increasing particle sizes, deposition occurs in the higher areas of the respiratory tract. A minimum in lung deposition occurs at 0.5 micron, and a maximum at 5 microns. Particles larger than 5 microns are retained by the upper respiratory tract and do not reach the lung. The nasal air passage acts as a trap or filter for these larger particles.

FIGURE 2



Deposition in Respiratory Tract

The rates of clearance of material from the respiratory tract are also important because they influence the tissue exposure time and thus determine the degree of radiation hazard to the lungs. The clearance of material from the lungs has not as yet been clearly delineated. However, it is thought that three mechanisms play a role in the removal of particulate material. These are ciliary action, transfer of soluble material across the alveolar membrane and phagocytosis. The action of ciliated epithelium in combination with mucous secretion results in a rapid "escalatorlike" upward movement

of material deposited in the respiratory tract above the terminal bronchioles. Materials in the ciliated upper portion of the respiratory tract are removed to the G.I. tract within hours, or at most, a few days. Ciliary action is a continuous process and accounts for the removal of the largest fraction of particles from the respiratory tract.

Relatively soluble material is transferred across the alveolar membrane into the bloodstream, and thus enters the circulation in minutes, or at the most, a few hours. The material appears equally rapidly in the organ of ultimate deposition. The radiation dose to the lungs from such soluble material is much less than that received by the organ of ultimate deposition, which is usually the skeleton, because of the brief transit time in the lungs.

To a limited extent, the so-called insoluble materials are also absorbed through the lung and the G.I. tract.

The third method for removal of particulate material from the lung is phagocytosis, that is, engulfment of a particle by a phagocytic cell. A phagocytized particle may be moved into an alveolus and transported upward, or the phagocyte may enter the lymphatic circulation and be transported to the lymph nodes.

To provide a basis for estimating the accumulation of the many types of radioactive material in the lung in situations where actual data are not available, the International Committee on Radiation Protection (ICRP) has derived a model to describe general respiratory characteristics of deposition and clearance, as shown in figure 3. The total deposition of (50 percent plus 25 percent) or 75 percent for readily soluble compounds is conservative for most size ranges. The figure is 25 percent for deposition in the lung is based on animal studies, and may vary widely. For insoluble material, in addition to the 50 percent which is removed from the upper respiratory tract and swallowed, an additional 12.5 percent is removed from the deeper portions of the lung by ciliary action and swallowed.

The overall elimination rate of fission products from the lung can be described by a series of exponential functions (rate proportional to level), and over a longer period of time by a power function (rate of removal decreases geometrically with time). These rate values are needed to provide meaningful calculations of radiation dose.

FIGURE 3

Distribution of particulates in respiratory tract

Distribution	Readily soluble compounds	Other compounds
	Percent	*Percent*
Exhaled	25	25
Deposited in upper respiratory passages and subsequently swallowed	50	50
Deposited in the lungs (lower respiratory passages)	[1] 25	[2] 25

[1] This is taken up into the body.
[2] Of this, half is eliminated from the lungs and swallowed in the first 24 hours, making a total of 62.5 percent swallowed. The remaining 12.5 percent is retained in the lungs with a half-life of 120 days, it being assumed that this portion is taken up into body fluids.

It can be seen from the preceding discussion that the body has certain natural defenses against inhalation of fallout. First, the nasal passages and lungs act as a filter against large particles. Secondly, the alveolar and G.I. tract membranes filter on the basis of solubility.

Finally, much of the material which gains entry into the lungs is transferred to the intestinal tract where it is lost through normal elimination. In addition to these physiological protective factors, many of the fallout fission products produced have very short radioactive half-lives.

Very few data exist correlating a given amount of an internal emitter and a specific pathological response. Information on pathological injury to the lungs of human beings is derived largely from data on the effect of external radiation in the treatment of cancer of the breast and intrathoracic neoplasms. Two main types of lesions are formed, radiation pneumonitis and radiation fibrosis, representing different types of damage to the alveolar cells and wall. While individual variation in response to radiation are very large, there is a definite correlattion of the frequency of the above lesions with external dose.

Clinical experience on the effects of radioactive material deposited in the lungs is derived primarily from miners who were exposed for long periods to radium dusts and radon gas in mines. The best known cases of lung cancer caused by radium are those that occurred in the miners of Joachimsthal and Schneeberg in Czechoslovakia. While an increase in the occurrence of lung caner of the order of 50 percent was observed as compared with the general population, the etiology of the cancer is linked only circumstantially to the radium.

Other date on the pathological effects of radiation to lung are meager, and are based in part on experience with individuals exposed accidentally to radiation or radioactive materials or to high doses of therapeutic radiation. In accidental cases, the radiation dose received is most often unobtainable. Data on the late effects resulting from radiation therapy are very scarce, as frequently the followup on such effects is not made, and further, the study requires difficult statistical analysis.

The best source of data is the study of radiation effects on laboratory animals. From animal experimentation it is concluded that lung as a tissue has only moderate radiosensitivity. Damage is observed in lung tissue only after a large acute dose or repeated smaller doses of external radiation.

There is no question that radiation from internal sources can produce lung cancer, but it is not as yet possible to equate the changes produced with given levels of radiation dose. The best estimate of the external dose required to produce pulmonary fibrosis and pneumonitis lies in the range of 800 to 2000 rads, with a mean dose of about 1,000 rads. The induction of pulmonary cancer from radioactive material in experimental animals requires a dose of about the same order. The smallest dose to the lung which produced malignant tumors in mice was reported as 115 rad, following administration of 0.003 μc $Pu^{239}O_2$, and 300 rads after administration of 0.15 μc $Ru^{106}O_2$. However, other studies with mice have indicated that 2,000 rad was the threshold dose for lung tumor formation. Actually, almost all of these studies utilize intra-tracheal administration of the material for experimental ease. It is difficult to compare such an exposure to one deriving from true inhalation.

FIGURE 6

Internal radioactive contamination of Marshallese pigs exposed to fallout from the Mar. 1, 1954, nuclear detonation [1]

	Beta activity d/m/total sample × 10^{-3}			
	Gross activity	Sr^{89}	Ba^{140}	Rare earths
Skeleton	8,745	5,380	595	850
(Total, percent)	(100)	(62)	(6.8)	(9.7)
Lungs (alveolar)	1.3	0.24	0.22	0.57
Stomach	1.6	0.26	0.62	0.80
Small intestine	2.5	0.73	0.69	0.69
Large intestine	14	5.0	2.8	4.0
Liver	29	0.47	0.27	5.9
Kidney	3.2	0.18	0.30	0.61
Remaining carcass	455			

Thyroid dose	100–150 rep—(estimated from early analysis of urine).
Total external gamma dose	330 r.
Internal beta activity	4 μc.

[1] These values are the average of 2 young adult pigs which were analyzed 3 months after detonation.

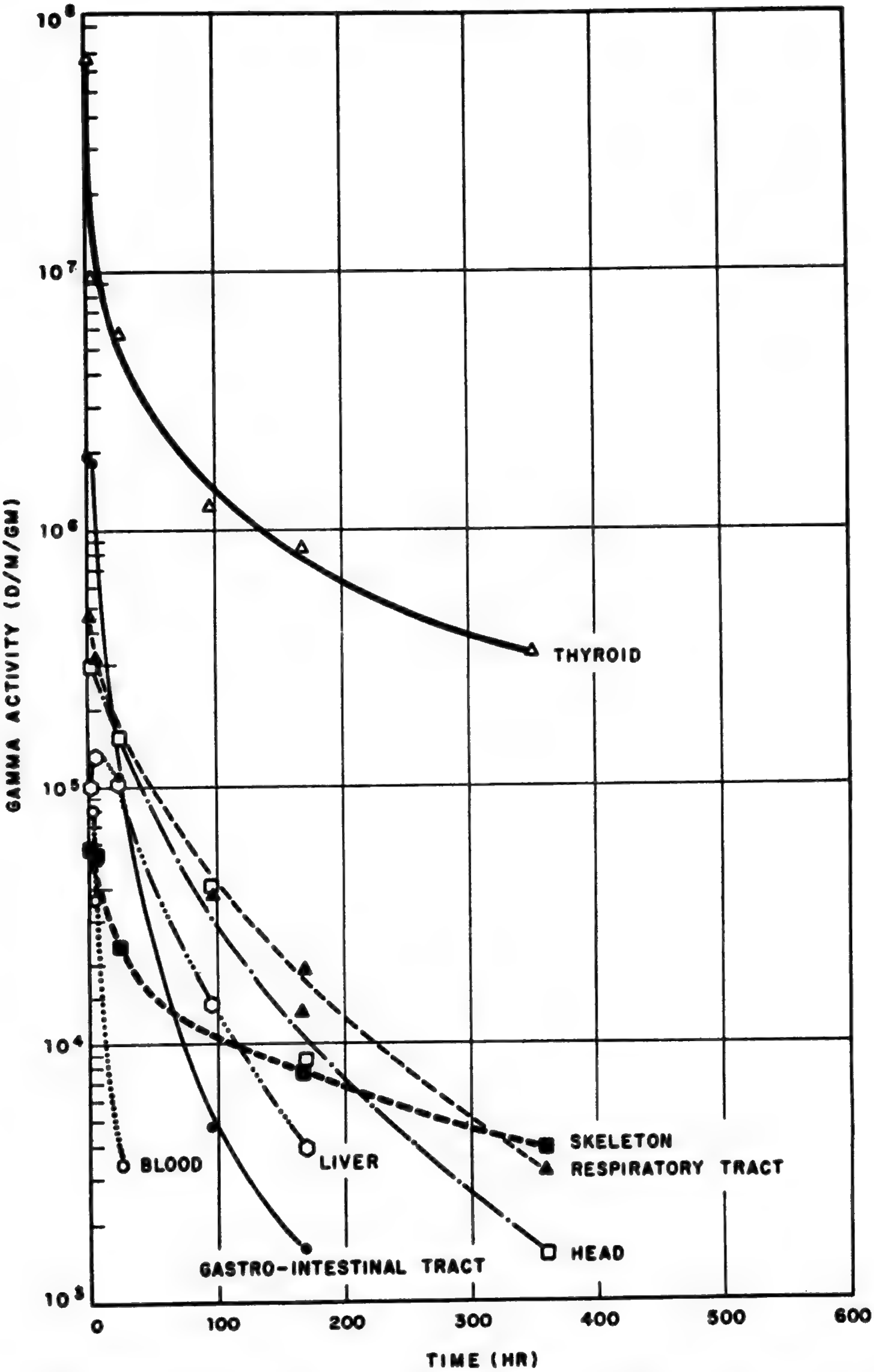
It can be seen that I^{131} and the shorter-lived I^{132}, I^{133}, and I^{135} contribute the highest individual tissue dose (100–150 rep to the thyroid). Although this is a large dose, studies with sheep indicate that doses of 16,000 r. are required to produce minimal changes in cell structure, and 50,000 r. are required to produce definite acute cell damage and hypothyroidism. Of the remaining fission products, Sr^{89} contributed the major portion of the beta dose to the skeleton. Thus the contribution of the total internal contamination in the Marshallese was small as compared to the 175 r. external gamma dose which they received.

In laboratory experiments designed to reproduce exposure to early fallout from various types of nuclear detonation, products from 2-day-old neutron bombarded uranium associated with various types of carriers were employed as fallout simulants.

In these inhalation experiments mice received an acute exposure from many of the short-lived radioisotopes not previously studied. The distribution, retention, and clearance of the fission products in these animals confirm the fact that the uptake and metabolism of the inhaled radioactive particles depend largely on the physical and chemical characteristics of the carrier material. The internally deposited radioactivity in the lungs, as well as in the skeleton and soft tissues (as shown in figure 7) decayed rapidly because the activity of the aerosol was contributed chiefly by short-lived radioisotopes and the biological loss of material from the lungs and soft tissues was very rapid.

While, as mentioned previously, the calculation of the internal radiation dose from fallout with any degree of precision is difficult, a rough approximation based on the experimental data here is feasible. To evaluate dose to individual tissues following this acute inhalation exposure, the activity per gm tissue as a function of time was determined. The greatest activity per gm tissue was observed in the thyroid at 1 hour following exposure. The total dose received by each organ for comparable energies is proportional to the area under its curve.

FIGURE 7



FROM: STANTON H. COHN, "RADIOTOXICITY RESULTING FROM EXPOSURE TO FALLOUT SIMULANT," REPORT USNRDL-TR-118 (1957), FIG. 5.

UPTAKE & RETENTION BY MICE OF A SIMULANT OF FALLOUT PRODUCED BY A LAND BASED NUCLEAR DETONATION.

(MICE WERE EXPOSED TO 2-DAY OLD FALLOUT.)

RADIOLOGICAL HAZARD EVALUATION - A CRITICAL REVIEW OF PRESENT CONCEPTS AND A NEW APPROACH THERETO

by

E. L. Alpen

U. S. Naval Radiological Defense Laboratory
San Francisco 24, California

In the older approach, discussed in the previous section, the same basic set of effects data was applied in all of the above three situations. As the problems are more or less unique for each category some flexibility might be gained by altering the judgement criteria for the needs of the system.

GENERAL BASIS FOR APPROACH

Before making this subdivision it is probably worthwhile to first state a more or less unified concept of hazard and then adapt it to each situation.

When an individual is exposed to mixed ionizing radiations two specific organ systems are conceivably affected to an extent capable of causing either death or incapacitation. These organ systems are the bone-marrow-intestinal complex which may suffer physiological failure from the result of penetrating ionizing radiation; and the skin which can, as the result of the loss of its integrity, cause death or severe incapacitation. The latter organ can respond to radiation of all energies which penetrate to effective depths in the epithelium. If these are designated respectively deep effect and surface effect it is possible then to organize our thinking on the basis of two response criteria, one associated with the deep effect and one associated with surface effect. We shall refer to these as "deep hazard" and "surface hazard". They can be treated more or less independently in terms of acute effects as long as either one is relatively large with respect to the other. Data have been developed to show that the response to penetrating ionizing radiation is not detectably altered by superficial radiation as long as severe skin damage is not present.[13] In the presence of severe skin damage, on the other hand, it has been shown by Alpen, et al[15] and Brooks and Evans[14] that thermal burns of thirty percent or more of the body area reduce the X-ray LD_{50} appreciably.[14,15] Except for this limiting case we shall consider the two effects to be independent. When this assumption is made, an instrumental requirement is established for a detection device capable of assessing deep hazard independent of energy of the radiation

(SYNERGISM OF THERMAL BURNS AND DEPRESSED WHITE BLOOD CELL COUNT DUE TO RADIATION)

THE DEEP HAZARD

In Figure 3 is shown the relationship between the energy of the ionizing radiation and the dose effective in producing lethality in dogs. The data are for bilateral exposure to X-ray sources with rather broad energy bands, but it is reasonable to assume that only minor readjustments would need be made for more restricted energy limits. From the relative body and bone dimensions of dog and man it is possible to derive a curve of energy vs. effectiveness for lethality in man. This curve is also shown in the same figure. For estimation of hazard the instrument used in measuring dose, either portable radiac, pocket dosimeters or film badges should have a sensitivity which is reciprocal to this curve. We might state the requirement as follows. The instrument must have unit sensitivity for gamma radiation above approximately 80 KEV. At 30 KEV the sensitivity must be reduced to 50% of the maximum and it must detect no more than 1% of the gamma radiation of 15 KEV or less.

The principal basis for this requirement is the need to appropriately weigh whatever small amount of low energy gamma radiation is present, and, of much greater importance, to insure that none of the beta radiation present in the same environment is measured.

It has been mentioned in preceding sections that when radiation is from an extended plane surface or a ring type source that on the purely physical basis of depth dose enhancement the radiation will be 20 to 30% more effective than unilateral radiation at the same total dose. With this consideration in mind it is necessary to adjust the dose levels which will be predicted to yield a given response and also to require a geometrical responsiveness within the instrument that yields equal meter deflection for radiation from any angle. It has been shown that existing instrumentation is seriously deficient in this latter regard. Work[11] has shown that the shielding of the detector provided by the instrument case and the operator leads to a drop in detection sensitivity in the rearward quadrant. It seems that one of the more pressing requirements in radiac development at this time is correction of this deficiency.

Assuming that the requirements of energy and geometrical dependency of sensitivity are met in the detector, it remains for us to establish a series of standards of biological response that might be useful in implementing the three problems outlined in the previous section.

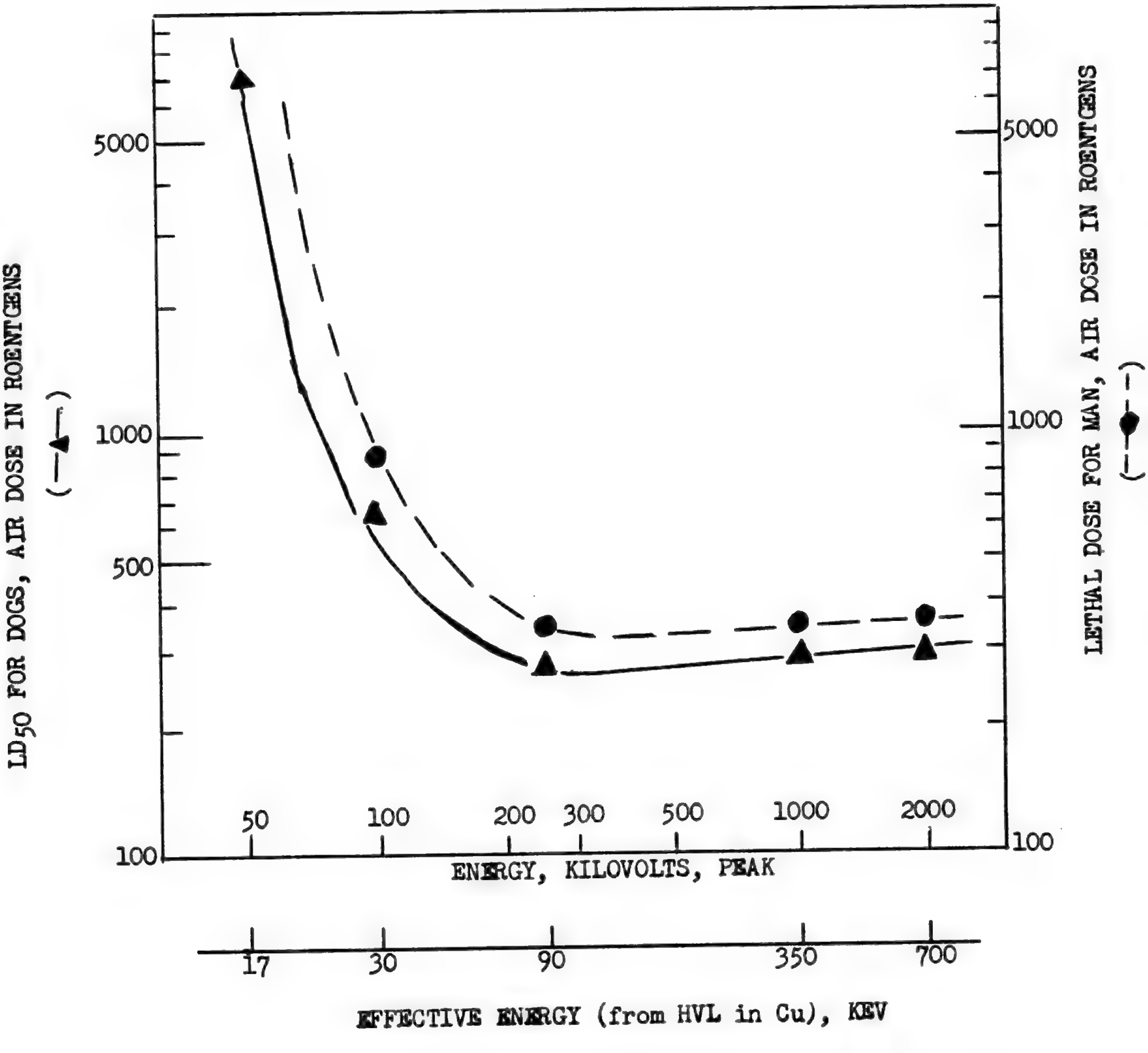


Fig. 3 Lethality of Ionizing Radiation as Related to Energy.

Solid line connects measured values of the LD_{50} for dogs, bilateral radiation. The dotted line connects the estimated values for man assuming a phantom thickness of 27 cm and an average bone thickness for marrow shielding of twice the value which would be found in the dog.

Given the data presented in Table 3 it is possible to construct an operational table similar to that formulated for deep hazard. Again it is possible to divide the dose range into two regions using the same criteria as were applied for the deep hazard. If severe erythema is accepted as the acute effect which will incapacitate, then a dose of 600 rad is set as the upper limit for operation based upon the criteria of maximum acceptable acute effects. The same reasoning holds as for the 9-150 r region of deep effects. Hazard is linearly proportional to accumulated dose up to this maximum figure. For doses over 600 rad the following table should be applied in accepting or rejecting maximum exposure levels.

Table 4

ACUTE EFFECTS OF IONIZING RADIATION ON SKIN

Estimated Dose Required (EDR) in < 1 week	Effect
0-600 rad	No acute effects.
600-2000 rad	Moderate early erythema.
2000-4000 rad	Early erythema under 24 hours. Skin breakdown in 2 weeks.
4000-10,000 rad	Severe erythema in < 24 hours. Severe skin breakdown in 1-2 weeks.
10,000-30,000 rad	Severe erythema in < 4 hours. Severe skin breakdown in 1-2 weeks.
30-100,000 rad	Immediate skin blistering (less than 1 day).

Modifying Factors

Recovery rates for skin are as yet not extensively determined but one published report on rat skin[20] indicates that recovery is probably more rapid for skin than for deep effects. No information is available

as to permanent non-recoverable fraction. As a rule of thumb it is probable that a factor of 2 could be applied to the above tabulated values to get equivalent EDR's for 1 month exposure. The same remark is appropriate here that was mentioned under deep effects; the time schedule indicated in the table will not hold for protracted radiation.

Shielding is of critical significance for protection from the surface hazard. The dose rate to clothed surfaces of the body will be appreciably reduced by the shielding afforded by the covering. Condit, Dyson and Lamb[21] have measured the absorber characteristics of several military uniform fabrics as shown in Table 5.

Table 5

ABSORBER CHARACTERISTICS OF FABRICS

Material	Wt/unit Area
Denim work pants	31 mg/cm^2
Cotton work shirt	17
Woolen pants	34
Knitted wool (sweater)	31
Close woven rayon	6.3

A normal two layer fatigue uniform would have absorption characteristics approaching one half-value layer for mixed fission products. Heavy clothing will be equivalent to roughly two half-value layers. Protection factors of 0.5 and 0.25 are then applicable to measured dose rate for areas covered with clothing.

Attenuation in air of beta radiation provides protection for upper portions of the body. However, direct measurement of the dose rate at the point of interest makes the necessary correction for this variable.

13. Alpen, E.L. and D.M. Jones. The Effect of Concomitant Superficial Radiation on the Lethality of 250 KVP X-Rays in Dogs. USNRDL-TR-200, February 1958 (Unclassified).

14. Brooks, J.W., E.I. Evans, W.T. Ham and J.D. Reid. The Influence of External Body Radiation on Mortality from Thermal Burns. Ann. Surg., 136, 533 (1952).

15. Alpen, E.L., and G.E. Sheline. The Combined Effects of Thermal Burns and Whole Body X-Irradiation on Survival Time and Mortality. Ann. Surg., 140, 113 (1954), USNRDL-402, May 1953.

16. Broido, A. and J.D. Teresi. Tolerance in Man to External Beta Radiation. USNRDL TM-4, 6 Aug 1954 (Unclassified).

17. Wilhelmy, E. On the Reaction of Skin to Long Wave Length X-Rays and Cathode Rays. Strahlentherapie 55, 498, (1936).

18. Moritz, A.R. and F.W. Henriques. Effects of Beta Rays on Skin as a Function of Energy, Intensity and Duration of Exposure. II. Animal Experiments. Lab. Invest. 1, 167 (1952).

19. Alpen, E.L. and B.W. Shumway. Concept of "Critical Tissue" in Beta Ray Dosimetry. USNRDL TM-48, 10 Nov 1955.

20. Jacobsen, E.M., A.K. Davis and E.L. Alpen. Effect of Fractionnation of Beta Radiation upon Rat Skin. Fed. Proc. 16, 66 (1957).

21. Condit, R.I., J.P. Dyson and W.A.S. Lamb. An Estimate of the Relative Hazard of Beta and Gamma Radiation from Fission Products. USNRDL Technical Report AD-95(H). April 1949. (Unclassified).

The Determination of Internally Deposited Radioactive Isotopes in the Marshallese People by Excretion Analysis#

Kent T. Woodward, Ariel G. Schrodt##, James E. Anderson,

Harry A. Claypool, and James B. Hartgering

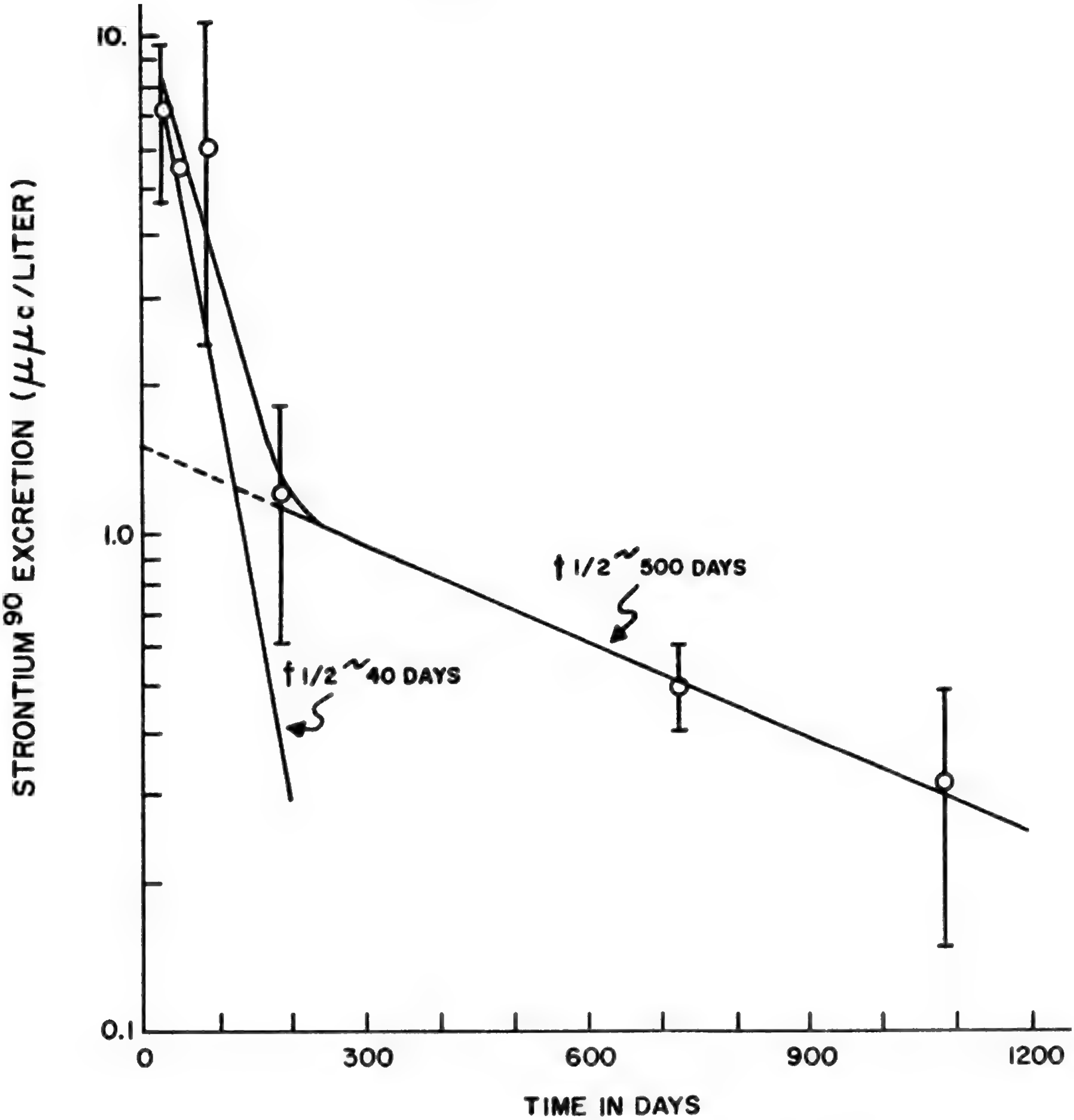
Division of Nuclear Medicine

Walter Reed Army Institute of Research

Washington 12, D. C.

Work done under the auspices of The Surgeon General, United States Army, and in conjunction with the Division of Biology and Medicine, Atomic Energy Commission

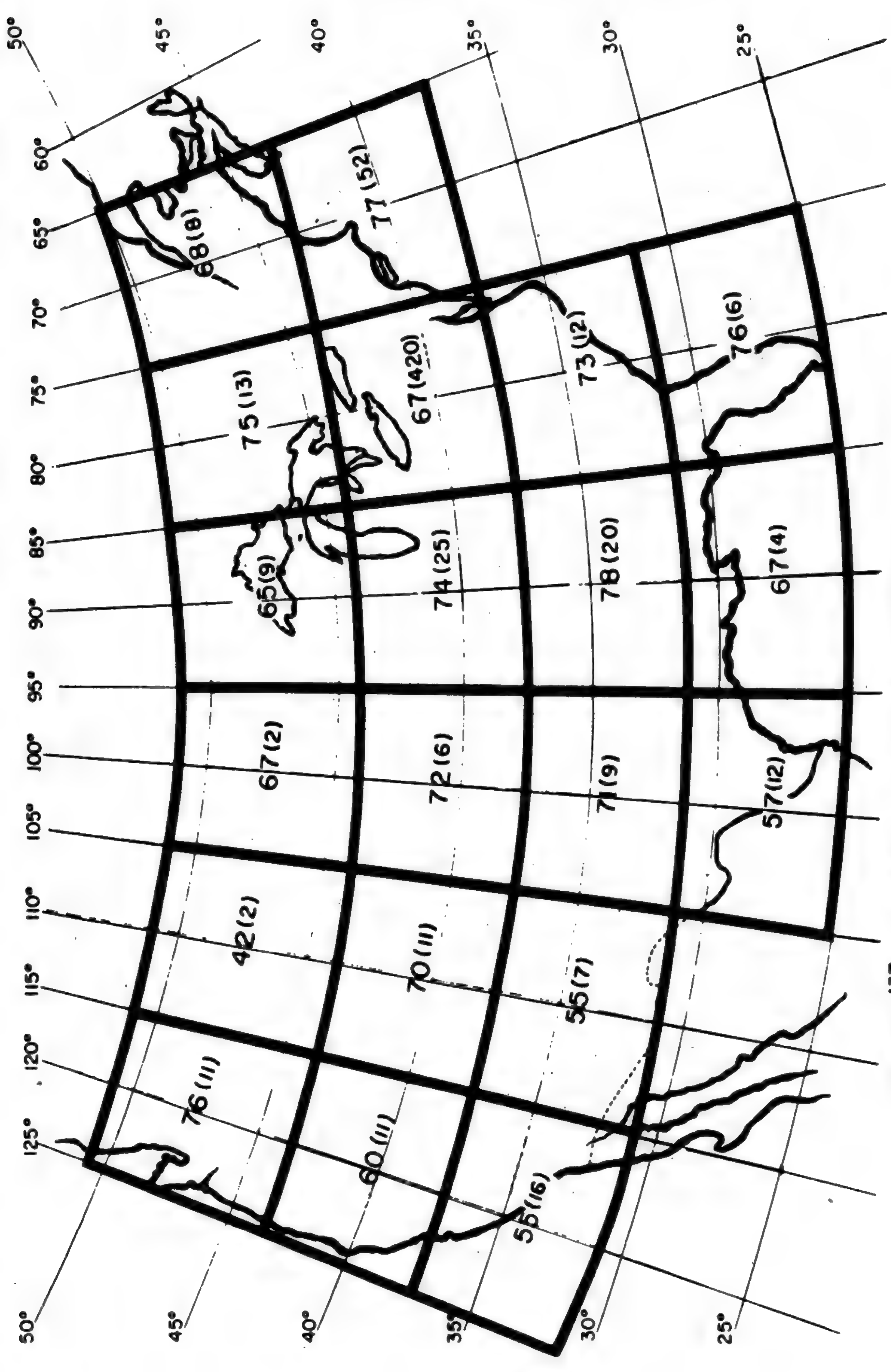
Present Address: Nuclear-Chicago, Chicago, Illinois



RONGELAP.

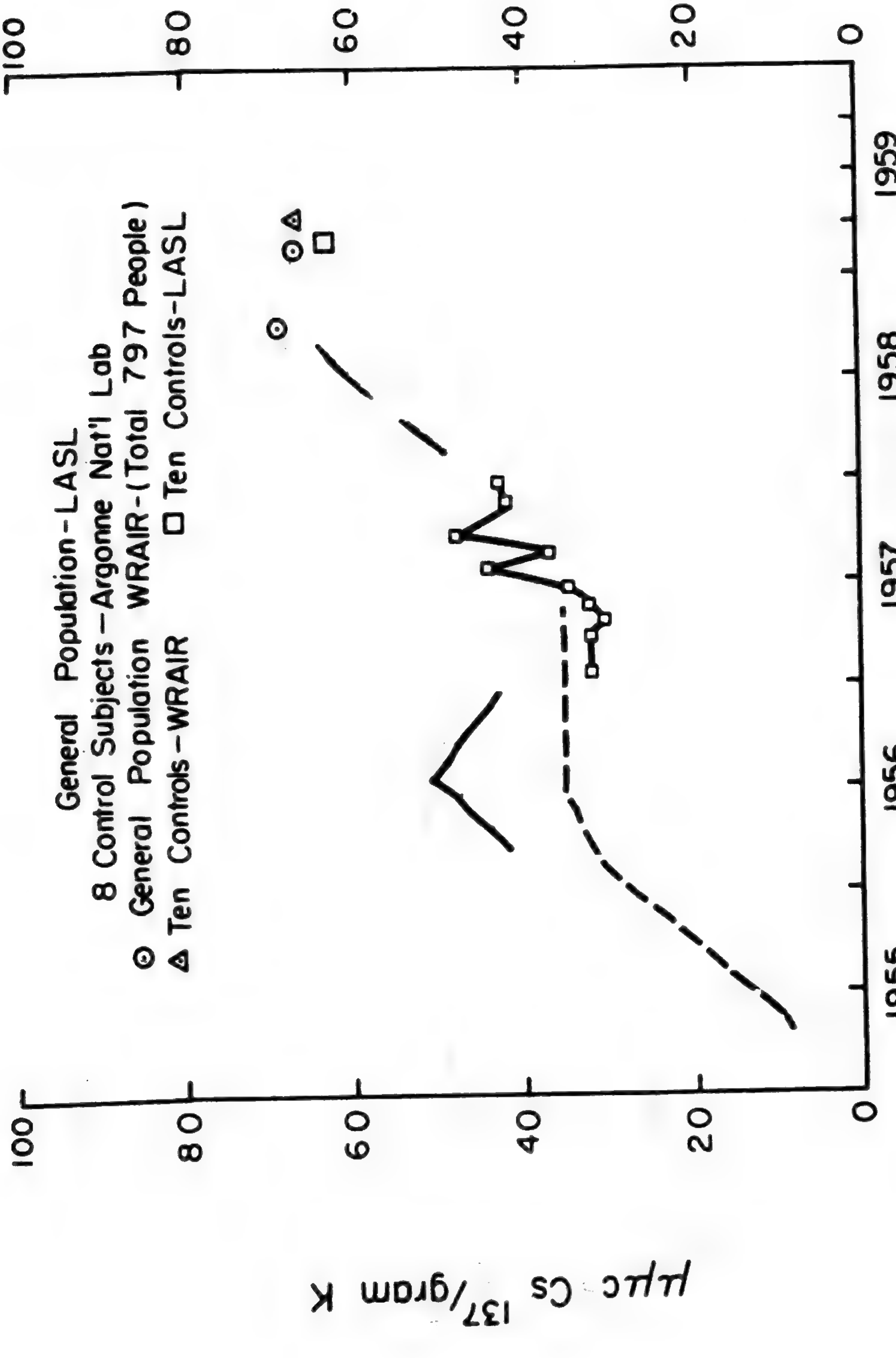
Figure 2. Excretion Levels of Urinary Strontium^{90} at Various Times After Exposure

The metabolic behavior of strontium as outlined in Supplement #6 of the British Journal of Radiology was used to estimate body burden, etc. from urinary excretion levels of strontium^{90} (Appendix). The fraction of strontium absorbed from the gastro-intestinal tract is 0.6 and the biological excretion rate from the total body is 190 days. Of the absorbed fraction, 0.25/0.60, about 42 per-cent is deposited in bone and the biological half-life is 4000 days.



CESIUM 137 LEVELS (μμc/gmK) IN NORMAL
U.S. SUBJECTS JULY 1958 – MARCH 1959
(TOTAL 797 INDIVIDUALS)

Figure 9

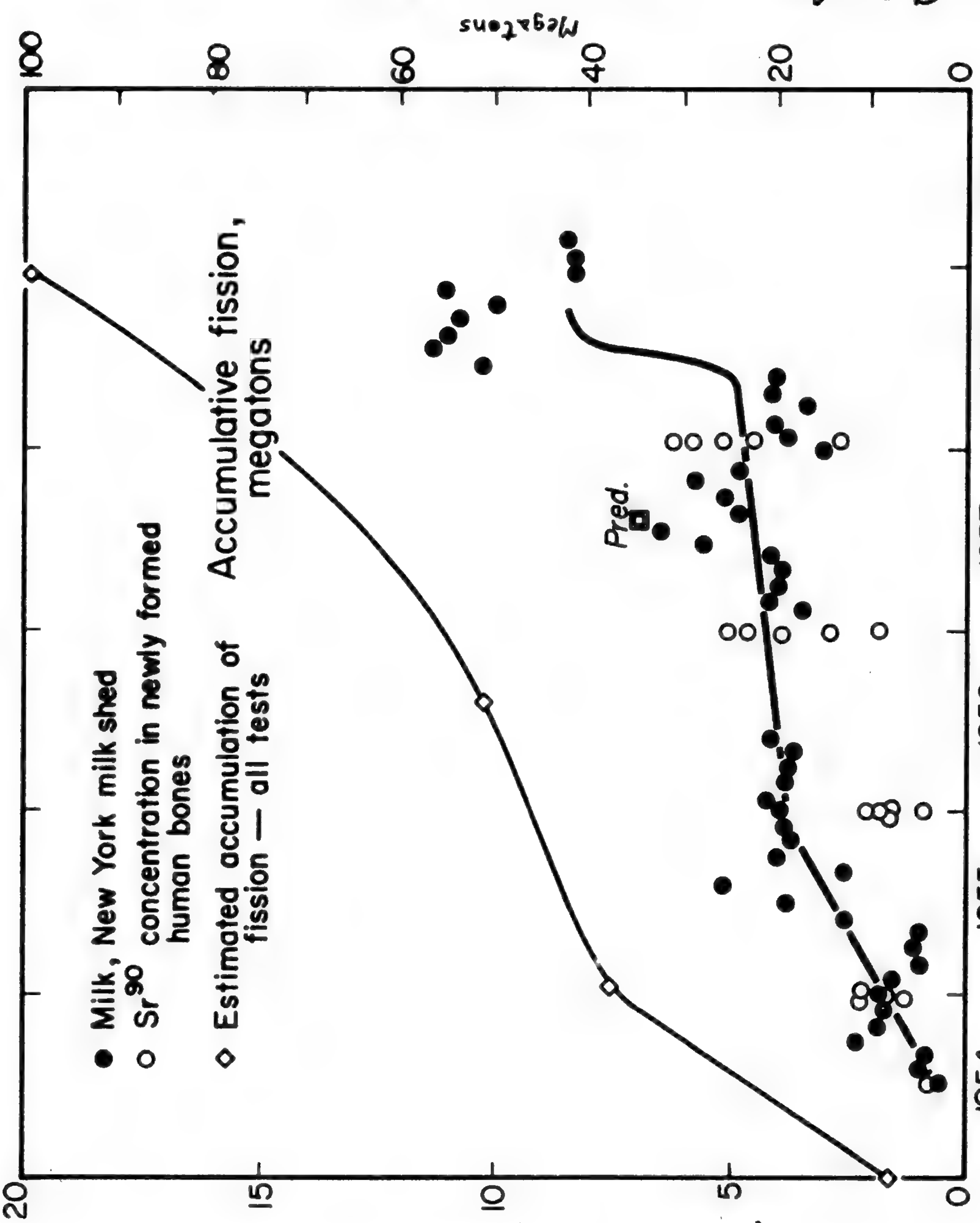


COMPOSITE DATA—CESIUM—137 LEVELS
IN UNITED STATES POPULATION

Figure 10

92 fission megatons of tests to end 1958
give a mean of 10 $\mu\mu$Ci Sr^{90}/gm Calcium
$\Rightarrow$ 2.8 mR/year to bone in the
Northern Temperate Zone.

FIGURE II



1 $\mu\mu$Ci Sr^{90}/gm of Calcium in bone $\equiv$ 2.8 mR/year
Calcium = 1/7th of bone mass.
Sunshine or Strontium Units (S.U.)
($\mu\mu$Ci Sr^{90}/gram of bone calcium)

STATEMENT OF EUGENE QUINDLEN,[1] OFFICE OF CIVIL AND DEFENSE MOBILIZATION

Mr. QUINDLEN. Mr. Chairman, members of the committee, this presentation is an analysis of the effects of the attack specified by the committee on the people of the United States.

As you recall, from our discussion of the other day, this is an attack of 263 weapons ranging from 1 to 10 megatons upon this country for a total megaton average of 1,446.

The figures which I will present today are national figures only (p. 650).

As you requested, we are preparing a State and metropolitan area breakdown of these figures and will present them to the committee as requested, tomorrow morning.

There are many variables in placing an attack of this type and these variables can affect the final nature and place of an attack and can affect the number of casualties produced by an attack.

The specific attack described by the committee on these targets and under these circumstances, could have killed about 19.7 million persons the first 24 hours. An additional 22.2 million persons would have been so badly injured that they would subsequently die of the injuries, and there would have been about 17.2 million additional persons injured who could be expected to recover from the injuries received.

The chart which we have there summarizes these figures. Of those killed, about 25 percent would have died as a result of radiation alone, and about 75 percent as a result of blast and thermal injuries, combined to a great extent with radiation injuries.

Many of those people close in to a weapon who would die of blast and thermal injuries would also have received sufficient radiation to kill them. We have listed these, however, as blast and thermal injuries.

Of the surviving injured of 17.2 million, about 6.3 million would have had blast and thermal injuries and about 10.9 million would have had fallout injuries alone. This would be a serious blow, but even with this weight of attack we should look to the question of what is left, what does the country look like at this point.

First of all, about three out of every four persons in the United States would survive this particular attack. On the other hand, one out of four would not survive. These are the facts of life if a nuclear war should ever come to our borders.

This is the picture which OCDM has been portraying for the American people over and over again in speeches, in pamphlets, on the radio, on television, and in the newspapers.

This threat and means to meet it were highlighted in the pamphlet "Facts About Fallout," of which 8 million copies have been distributed since its initial publication in 1958, and in "Handbook for Emergencies," distributed in 42 million copies.

It is reiterated in the new OCDM pamphlet, "The Family Fallout Shelter," which is now being distributed in total number of 50 million copies.

---

[1] See biography, p. 12.

Dr. DUNNING. No, sir; I don't know how we can do it.

I can give a personal opinion as to its desirability.

Senator HICKENLOOPER. Do you agree it would be highly desirable if the Russian people could have it thrust upon them what the results of an atomic attack would be in their own country?

But we do not seem to be able to get that across. We only seem to be able to get out to our own people what would happen to us in case of atomic attack.

The other fellow does not seem to get very much concerned about what would happen to him, which has something to do psychologically with attitudes toward international association, I am afraid.

Thank you very much.

Representative HOLIFIELD. Thank you, Dr. Dunning.

Dr. DUNNING. Thank you.

(The complete formal statement of Dr. Dunning appears starting on p. 436.)

Representative HOLIFIELD. Our next witness is Mr. W. E. Strope, National Radiological Defense Laboratory.

He will speak on survival measures.

Representative HOLIFIELD. Mr. Strope, we are glad to have you back again. You testified for our committee before. We will be glad to hear from you at this time.

STATEMENT OF WALMER E. STROPE,[1] HEAD MILITARY EVALUATIONS DIVISION, U.S. NAVAL RADIOLOGICAL DEFENSE LABORATORY

Mr. STROPE. Thank you, Mr. Chairman and members of the committee. Prior testimony has established the dimensions of the attack under consideration and the number of casualties that might be expected. It is my purpose to summarize the possibilities of defense against this threat with emphasis on the problem of protection against radioactive fallout.

I propose to start by indulging in a little survival arithmetic in order to illustrate the nature of the defense problem. I have taken here (fig. 1, p. 683) initially the heavy fallout area, approximately 3,000 r/hr at 1 hour.

In this attack approximately 20 percent of the population was in a region of this level. On the other hand, 80 percent are not in so serious a condition. I will cover them shortly. But let us consider the heavy fallout area and what the nature of our problem is.

In this area the dose during the first year—this is without countermeasures, simply in the open—is approximately 12,000 roentgens. This, of course, is more than is necessary to kill a person.

Now of this first year's dose—which is the only period that we will consider, because the doses in subsequent years are so very much smaller they can be neglected in this argument—the dose in the first 2 weeks is about 10,000 roentgens.

---

[1] Born in Mason, Mich., Apr. 9, 1918; married, 2 children; BS, Webb Institute of Naval Architecture, 1942; engineer, Bureau of Ships, Washington, D.C., 1942–48; head, Military Evaluations Division, USNRDL, 1948 to present. AAAS; ORSA. Navy Distinguished Civilian Service Award, 1957, for contribution in field of atomic defense.

Ultimately it is hoped to prove-test the shelter by occupying it for a 2-week period with the full complement of 100 persons.

The end result will be the first fully tested design of a high performance fallout shelter available in this country.

Now, I would like to turn to the postshelter problem of recovering the use of essential facilities needed to reconstruct the economy. I would like to expand briefly on my previous statement that we think we can get a factor of 10 reduction at the present time. This statement is based on a considerable history of experimentation beginning with Operations JANGLE in 1952, and more recently field experiments have been conducted at Camp Stoneman in California, using simulated land fallout. Work of this type will continue under OCDM sponsorship at Parks Air Force Base. Areas of this base, which is being turned over to the Army shortly, have been set aside for USNRDL research work.

The principal weakness in present knowledge in reclamation stems from the fact that no experimental reclamation of actual facilities such as industrial plants, oil refineries, residential areas and the like, has actually been accomplished. All of our previous studies have been confined to typical elements such as streets, roofs, and so forth. Experimental decontamination of complex target facilities are planned for the near future. The results should indicate to what extent the effectiveness we have seen on typical elements, that is, a reduction factor of 100, can be expected in real situations.

The work should also result in well-designed procedures that can be used to train recovery crews on a countrywide basis. Meanwhile, we are estimating for OCDM, based on our present knowledge, the effectiveness and cost of reclaiming specific facilities considered essential for post-attack recuperation of the economy.

Now, continuing consideration of the fallout problem, I would like to consider the effects of various levels of protection on the human casualties caused by this particular attack for the committee. One of the difficulties here hinges on the definition of the term casualty. One interpretation might be whether a person lives or dies during the attack period. On the other hand, some criterion of injury might be selected that would consider either radiation sickness or the longer term effects that have been discussed in prior testimony, perhaps even genetic effects.

I shall avoid an arbitrary definition of radiation casualty by presenting calculations for this attack showing the fraction of the total population receiving various radiation doses, these doses being ones that might be used to define a casualty.

In making these calculations I consulted Dr. Joseph Coker, who is director of the National Damage Assessment Center, and who actually ran these calculations, and obtained an estimate of the fraction of the population located in areas that received various levels of fallout.

Using this information I obtained the results shown in my last chart (fig. 4, p. 692).

In the body of the table are the percentages of the total population of the country that would be found in various conditions. The table is broken into two parts. First the dose in the first 2 weeks is shown. This is the emergency phase and this is where the question of living and dying is decided in the main.

SURVIVAL ARITHMETIC

Heavy Fallout Area: 3000 r/hr at 1 hour

Dose during first year	12,000 Roentgens
Dose during first 2 weeks	10,000 "
Dose between 2 weeks and 1 year	2,000 "

EMERGENCY PHASE

10,000 Roentgens

OPERATIONAL RECOVERY PHASE

2,000 Roentgens

Shelter Shielding Factor	Emergency Dose	Reduction Factor	Operational Recovery Dose
10	1000 Roentgens	10	200 Roentgens
100	100 "	100	20 "
1000	10 "	1000	2 "
10,000	1 "		

Figure 1

43338 O—59——44

Useful Radiological Defense Systems

Heavy Fallout Area: 3000 r/hr at 1 hr

System Number	Emergency Phase Countermeasures	Operational Recovery Phase Countermeasures	Dose during First Year (roentgens)
1.	6-month shelter with 0.01 residual number	None	320
2.	6-month shelter with 0.001 residual number	None	210
3.	2-week shelter with 0.01 residual number	0.1 reclamation	300
4.	2-week shelter with 0.001 residual number	0.1 reclamation	210
5.	2-week shelter with 0.01 residual number	0.01 reclamation	120
6.	2-week shelter with 0.001 residual number	0.01 reclamation	30

Figure 2

References

1. "Radiological Recovery of Fixed Military Installations," TM-3-225 or NAVDOCKS TP-PL-13, Departments of the Army and the Navy (April 1958.

2. "A Method for Evaluating the Protection Afforded by Buildings Against Fallout Radiation" Office of Defense Mobilization, Washington 25, D.C. (Sept. 1957).

3. "Guide for Fallout Shelter Surveys, Interim Edition," Office of Civil and Defense Mobilization, Battle Creek, Michigan (Feb 1959).

4. RAND Report R-322-RC, "Report on a Study of Non-military Defense" (July 1958).

5. WT-1464, Operation PLUMBBOB, Project 32.3, "Evaluation of Countermeasures System Components and Operational Procedures".

6. W.E. Strope, et al, "A Study of the Specifications and Costs of a Standardized Series of Fallout Shelters" USNRDL Technical Report in preparation.

Representative HOLIFIELD. Thank you very much, Mr. Strope.

Mr. STROPE. Thank you, Mr. Chairman.

Representative HOLIFIELD. Before we recess for lunch, I have a paper that we requested from Robert Corsbie of the AEC which I would like to place in the record at this point.

Table 2

ESTIMATED CLINICAL COURSE AND HOSPITALIZATION REQUIREMENTS FOR HUMANS EXPOSED TO VARIOUS ACUTE DOSES OF PENETRATING RADIATION

Dose in r	Percent individuals following indicated clinical symptoms						Percent needing hospitalization	Maximal time of hospitalization weeks
	trivial	light	moderate	serious	grave	fatal		
0 - 200	98	2					none	0
200 - 300	1	33	64	2			2	6
300 - 400			6	68	26		94	7
400 - 500				3	58	39	100	9
500 - 600					6	94	100	11
above 600						100	100	11

Compiled from Gerstner

H.B. Gerstner, "Acute Radiation Syndrome in Man," U.S. Armed Forces Medical Journal, v.9, March 1958, pp. 313-354.

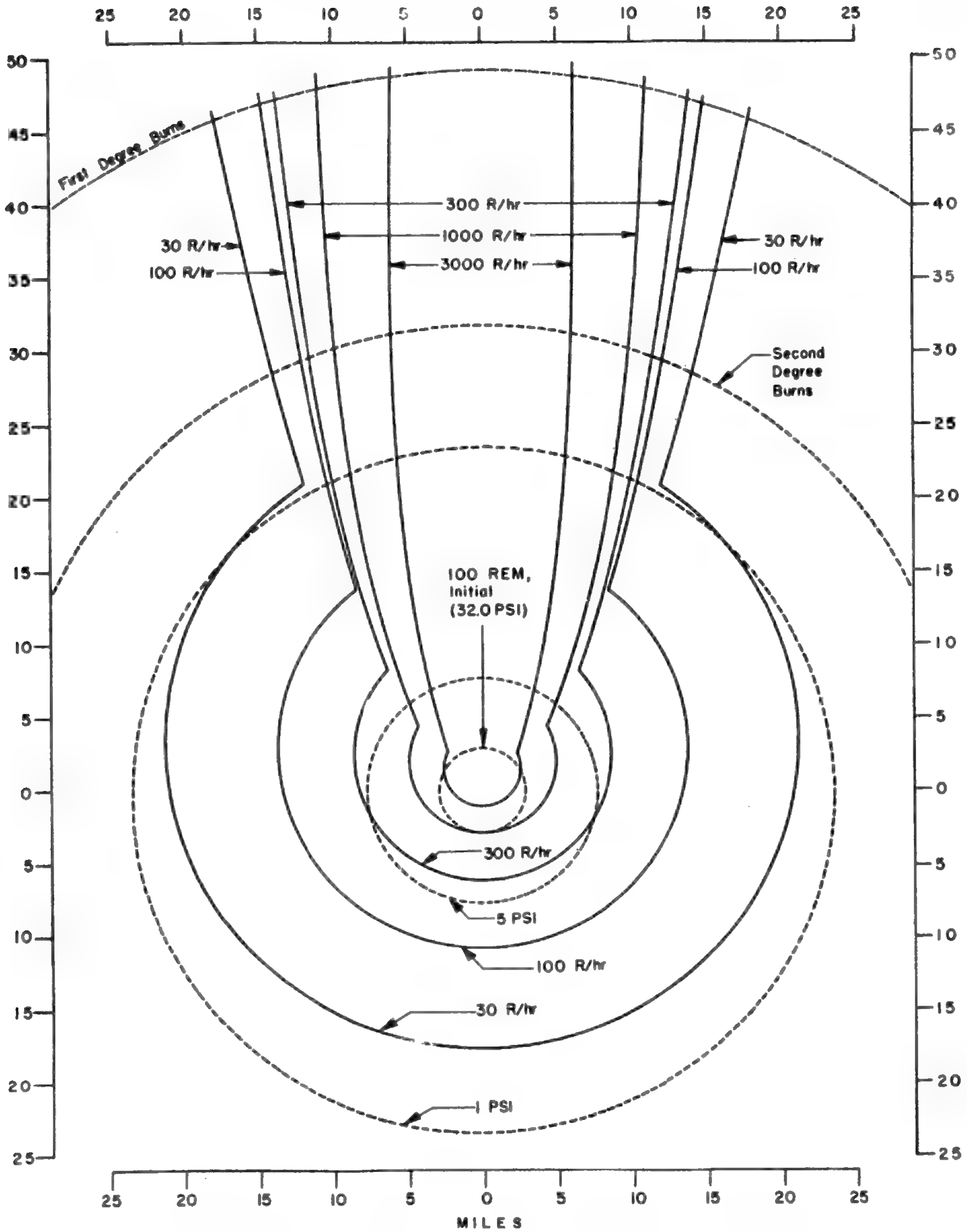


Figure 3

COMPARATIVE EFFECTS FOR A 20 MT SURFACE BURST

Residual radiation data — one hour reference dose rates — computed for a fission yield of 10 MT and an effective wind of 15 mph

BASED ON GLASSTONE ENW. 1957 WHICH SCALES UPWIND FALLOUT FROM 1952 "MIKE" TEST; OVERESTIMATING CLOSE-IN FALLOUT FROM LIGHTER CASED BOMBS WHICH PRODUCE LESS CRATER THROWOUT AND LARGE PARTICLES.

Representative HOLIFIELD. We will adjourn now until 2 o'clock this afternoon.

(Thereupon, at 12:40 p.m., the subcommittee was recessed, to reconvene at 2 p.m., the same day.)

AFTERNOON SESSION

Representative HOLIFIELD. The committee will be in order.

We will begin testimony this afternoon on environmental contamination resulting from nuclear war.

We will consider the following categories of environmental contamination:

1. Effects on animals.
2. Effects on soils and crops.
3. Effects on foods.
4. Experimental results of long-term effects.
5. Long-range implications.

Our first witness is Dr. Bernard Trum, director of the Animal Research Center of Harvard University Medical School.

Dr. Trum has had years of actual field and laboratory experience in conjunction with the AEC on the effects of radiation on animals.

Dr. Trum, we are happy to have you before us. You may proceed.

STATEMENT OF BERNARD F. TRUM,[1] D.V.M., DIRECTOR OF THE ANIMAL RESEARCH CENTER, HARVARD UNIVERSITY MEDICAL SCHOOL

Dr. TRUM. Thank you very much.

I appreciate the privilege of presenting this statement before the subcommittee, and although I shall limit my remarks to the effects of nuclear radiation on animals, I take the opportunity to express the deep interest of myself and my professional colleagues in veterinary medicine to the relation of this effect to man. However, that will not be a part of this paper.

The cattle of Alamogordo, as you know, were the first casualties

---

[1] Boston College, 1931 (B.A.).
Now York State Veterinary College, Cornell University, 1935 (D.V.M.).
Veterinary Corps, U.S. Army, 1935–58.
Professor of zootecnia, University of San Simon, Cochabamba, Bolivia, 1949–50.
Professor of zootechnics, University of Tennessee (1951–56) (director of total body irradiation project (No. 10), UT–AEC, Agricultural Research Laboratory).
Veterinarian, Division of Biology and Medicine, Atomic Energy Commission, Washington, D.C., 1956–58.
Representatve from American Veterinary Medical Association to the National Committee on Radiation Protection and Measurements.
Director, Animal Research Center and lecturer on Veterinary Medicine in the Department of Pathology, Harvard Medical School, Boston, Mass., 1958 to present.

DR. TRUM:

TOTAL BODY IRRADIATION

In 1912, Regaud et al. wrote about the effect of ionizing radiation on the intestinal mucosa of the dog. Since that time many domestic animals have served the investigator in his quest for knowledge concerning the biologic effects of radiation. It is enigmatic that massive doses of radiation are required to produce observable chemical changes and yet relatively small amounts of radiation kill. If the total exposure is accomplished in less than 24 hours, between 300 to 600 r usually destroys about 50% of mammals. The midlethal dose for common species of livestock at 30 days ($LD_{50/30}$) may be found in Table I. Some species seem to be more radiosensitive than others. However, considerable variations in lethal response are found in families or even among individuals of the same species (Kohn and Kallman, 1956a). Vegetative forms such as bacteria are more radio-resistant than mammalian. Physical as well as biologic variations make comparisons of results from different laboratories difficult.

TABLE I
MIDLETHAL DOSES OF IONIZING RADIATION

Species	$LD_{50/30}$(r)*	Radiation/	References
Dog	228-252	X-ray midline dose	Bond et al. (1956)
	265-312	X-ray air dose	Bond et al. (1956)
	335-530	X-ray, 21-500 r/hr	Casarett (1950)
	335	Co^{60} midline dose	Shively et al. (1956)
Rabbit	767	250 kvp	Grahn et al. (1956)
	1633	80 kvp	Grahn et al. (1956)
	1094	Co^{60}	Rust et al. (1955a)
Swine	618	Co^{60}, 50 r/hr.	Rust et al. (1954c)
Sheep	524	$Zr\text{-}Nb^{95}$	Trum (1955)
Burro	784	Co^{60}, 50 r/hr.	Rust et al. (1954a)
	651	Ta^{182}, 18-23 r/hr.	Rust et al. (1953)
	585	$Zr\text{-}Nb^{95}$, 20 r/hr.	Lane et al. (1956)
Bacteria	50,000-500,000	X or gamma	Schweigert (1954)
Parasites	25,000	X or gamma	Alicata (1951)

*LD 50/30 = The quantity of radiation in roentgens (r) that killed 50% of the test animals within 30 days after exposure.

$LD_{50/30}$ has not been determined for bacteria or parasites and the near sterilization doses quoted for them above are given only to show the relative radio-resistance of these forms.

/Mev = Million electron volts; kvp = kilovolt potential; r/m = roentgens per minute, a dose rate. Midline dose = dose measured at the approximate physical midcenter of an animal torso. Air dose = dose measured in air at point where the approximate physical midcenter of animal would have been during irradiation.

1. Dose

The expression of dose as used is itself variable since the roentgen, by definition, is an expression of quantity of energy absorbed by air. It is used to designate "free in air dose," "midline dose," and "absorbed tissue dose" as in Table I. Regardless of these variations, the biologic effects are in relation to the expressed dose. The dose is additive with various radiations (Vogel et al., 1955) and cumulative in a certain sense in so far as effects of previously received irradiations have a demonstrable effect upon the response to subsequent irradiations. The $LD_{50/30}$ for rats was reduced by 60% when reexposures were made at 60 days (Hursh et al., 1955).

2. Intensity

In man, it has been found that radiation of low intensity has little recognizable effect on the skin which has been explained as meaning that the lesions are being repaired as fast as they are produced. However, with radiations of moderate intensity at least, the effect is proportional to the dose.

TABLE II
LETHAL EFFECTS OF WHOLE BODY RADIATION OF DOGS

Rate (r/hr.)	$LD_{50/30}$ (r)
456.6	335
160.0	430
21 to 25	530

3. Dose Rate

Henshaw et al. (1947) reported a reduction of lethality by 70% of a given dose when the exposure time (dose rate) was increased tenfold. The amount of radiation to elicit a cutaneous reaction in man was doubled when doses were lengthened thirty times (McKee et al., 1943). Casarett (1950) found that the $LD_{50/30}$ for dogs at various roentgens per hour varied considerably (Table II). Mice exposed to similar doses in 90 minutes and in 24 hours from Co^{60} had an $LD_{50/30}$ of 930 r in one case and 1325 r in the latter (Vogel et al., 1956).

4. Fractionation of Dose

Fractionated doses or the continuous administration of radiation may differ in their effectiveness. However, if the fractionation is not great the difference may be insignificant. It may be possible to measure these differences but it is difficult to explain them.

Hursh et al. (1955) exposed rats to acute and fractionated exposures and found that a 600 r acute dose reduced the life span by 19%. When the dose was given in 10 daily doses of 60 r each, the life span was reduced 5.8% whereas there was no significant reduction in the life span of rats given 600 r in increments of 20 r a day. Kaplan and Brown (1952) reported that the fractionation and periodicity of exposure of black mice to radiation extended survival times and decreased the lethality of specific doses. Ellinger and Barnett (1950) demonstrated the effect of dose fractionation on mice. Brues and Rietz (1948)

reported that chickens given 1000 r at a rate of 43 r/minute had 100% mortality in 14 days. However, if the dose was given in two equal exposures with a 40-minute interval, the mortality was reduced to 88%. Four exposures of 250 r with 20-minute intervals between them reduced the effect to 81% mortality. The burro has been given fractionated doses of whole body radiation until death (Table III) (Trum et al., 1953; Rust et al., 1954a, 1955b; Haley et al., 1955).

TABLE III
LETHAL DOSE FRACTIONATED TOTAL BODY IRRADIATION OF BURRO (Co^{60})

Dose/day	Survival time (days)	Mean lethal dose (r)
400	8.3 ± 1.4	3320
200	14.1 ± 3.3	2820
100	23.3 ± 1.0	2330
50	30.2 ± 3.3	1510
25	63.0 ± 13.2	1575

TABLE IV
MEAN SURVIVAL TIME FOR ANIMALS EXPOSED TO DAILY DOSES OF IONIZING RADIATIONS

		Mean Survival (days)	
Daily dose	Burro	Rat	Guinea pig
90-100 r	23.3	48.4	20.2
20-30 r	63.0	332.6	68.8

Swine have been given fractionated doses of 50 r/day until death (Trum, 1956) and accumulated a mean lethal dose several times greater than the burro. Thus we find that one domestic animal that seems to be more resistant (burro, $LD_{50/30}$, 784) than another (swine, $LD_{50/30}$, 200-400 r) and the burro, although quite different in their response to acute whole body irradiation, have a similar response to the fractionated doses (Table IV) while the rat is quite different than either.

When continuously irradiated a dose of 140,000 r caused death of mice within 20 minutes (Henshaw et al., 1946). However, after massive doses of 3500 and 14,000 r all mice lived 4 to 5 days. Burros, sheep, and cows lived in a constant flux of Co^{60} gamma radiation (40-50 r/hour) for 90 to 120 hours before total physical collapse (Trum and Rust, 1952; Wasserman and Trum, 1955).

5. Quality of Radiation

The quality of the radiation is a factor in biologic effects. By quality, we mean the type and energy of radiation or, in the case of X-rays, the characteristic spectral energy distribution. Arbitrarily, we will speak of low-energy X-rays as those under 140 Kev, relatively high-energy X-rays as those between 140-250 Kev, high-energy X-rays as those between 250 and 3000 Kev. All gamma

energies of nuclides used in whole body radiation studies have been in the high-energy range.

Generally, the term quality refers to the penetrating power of the radiation which is directly related to energy. However, biologic effects are caused, as mentioned previously, by energy transfer or total absorbed dose. This depends not only on the quality of radiation as the initial energy of photon, but also the degradation of photons and geometry and tissue characteristics of the animal target. Cronkite and Bond (1956) have emphasized the importance of depth dose and dose distribution studies in large animal experiments, stating that the effectiveness drops off at the point that the distribution of the dose departs from uniformity whether due to energy of the photon or unfavorable geometry of the target.

6. Relative Biological Effectiveness (RBE)

The inverse ratio of the doses required of different radiations to produce a standard amount of given biologic effect is the relative biological effectiveness (RBE) of the radiations. The difference in properties of radiation can only be determined properly when the physical measurements throughout the target are accurately known - a most difficult task. RBE is often used to express differences measured by "biological dosimeters" and "air dose" comparisons. It will be recognized at once that the RBE for various radiations will be greatly influenced by the "end point" observed. The lethality of a radiation is perhaps the most common reference, however, carcinogenesis, cataract formation, and erythema are other biologic phenomena which have been used as "end points."

Evidence of experimental biologic effectiveness of various radiations has been offered by many. Boche and Bishop (1946) reported that the $LD_{50/30}$ for dogs exposed to 250 kvp X-radiation was 300 r and when exposed to 1000 kvp X-ray it was 335 r. They concluded that the relative biologic effectiveness of the 1000 kvp beam was 0.81. On the other hand, Bond et al. (1956) found no significant difference in the lethal response of dogs when midline doses from 250, 1000 and 2000 kvp X-rays were compared, the $LD_{50/30}$s being 252, 255, and 268, respectively. Shively et al. (1956) found the midline tissue dose for $LD_{50/30}$ of dogs exposed to Co^{60} gamma radiation to be 335 r. Since this is significantly higher than reported $LD_{50/30}$ midline doses for dogs exposed to X-rays under similar conditions, they concluded that the RBE of Co^{60} was 0.75 of the 250 kvp. Upton et al. (1956) found similar figures when Co^{60} gamma rays and X-rays were compared in their effect on mice. Kohn and Kallman (1956b) found the RBE of the 1000 kvp and 250 kvp X-ray in mice to be 0.839. Fuller et al. (1955), comparing the effect of 18 Mev electrons and 400 kvp X-rays on rats, concluded that the 400 kvp was 30% more lethal in the LD_{50} range. We suspect that the $LD_{50/30}$ for swine exposed to Co^{60} gamma radiations (618 r) indicates the greater biologic effectiveness of the 1000 and 2000 kvp X-radiation shown by Tullis et al. (1952) to have caused an $LD_{50/30}$ of 350-510 r. The difference in dose rates and depth dose were considered and may explain some of the observed differences.

TABLE V
COMPARATIVE LETHALITY OF AIR AND TISSUE DOSES OF DIFFERENT ENERGY RADIATION IN ANIMALS

	LD_{50} Rabbits		LD_{50} Mice	
Energy (kvp)	Air dose	Tissue dose	Air dose	Tissue dose
250	805	767	634	590
100	1332	1022	663	617
80	2525	1633	810	727

The studies cited generally indicate a decrease in RBE as the energy of the radiation increases. However, the results of Bond et al. (1956) cannot be disregarded nor can we ignore the limitations of this generalization. Grahn et al. (1956) have pointed out that the implication of nonuniformity of depth dose accounting for variations in the RBE of X-rays has not been well established. Variations in LD_{50} of mice were found with different energies in which very little difference was noted in depth dose (Table V). In both species cited in Table V, the higher energies were most effective biologically.

Burros were exposed to gamma radiation from 3 radionuclides, each with a different mean energy (Lane et al., 1956, Rust et al., 1953, 1954c). The results, given in Table VI, show a variation in $LD_{50/30}$. Since the slower dose rate or the lesser depth dose of diminishing energies should have reversed the results we may assume that a more important factor was involved. If it were a physical factor, then we may assume it to be a function of linear energy transfer (LET).

TABLE VI
LETHAL RESPONSE OF BURROS TO NUCLEAR RADIATIONS

Source	Mean energy	Lethal dose (95% confidence)	Rate (r/hr.)
Co^{60}	1.25	784(753-847)	50
Ta^{182}	1.20-0.18	651(621-683)	18-23
Zr^{95}-Nb^{95}	0.74	585(530-627)	19-20

To recapitulate, the physical factors of type and quality or radiations, dose, dose rate, dose fractionation, and relative biological effectiveness determine the response of the mammal to radiation. In addition to these factors, there are physiologic factors that must be taken into consideration.

7. Physiologic Factors

The body size of the animal seems to have very little to do with the response to ionizing radiation, as a perusal of the $LD_{50/30}$ (Table I) will indicate. The metabolic rate of species has little to do with radio-resistance although both of these factors may have slight bearing on survival of individuals. Sex differences in radiosensitivity have not been consistently demonstrated in the larger domestic animals. Mice under 15 days old survive longer than 30-day-old mice when irradiated but animals over 30 days old become increasingly more radioresistant. Mice from 45 days to a year old show little difference in response to radiation (Abrams, 1951; Furth and Furth, 1936; Quastler, 1945; Zirkle et al., 1946). Results of Hursh and Casarett (1955) indicate that perhaps the middle-age group is the more radioresistant, for older rats have a lower $LD_{50/30}$ than mature young rats.

When it was found that swine may survive several times as long as burros while receiving the identical daily dose of gamma radiation (Trum, 1956), it was assumed by some that the fat of the swine protected in some manner. Spiers (1946) reports that because of the low effective atomic number of fat, it can account for a small difference in sensitivity. In the case of the swine, however, the acute radiation studies indicated they were more radiosensitive than the burro (Rust et al., 1954c); thus the fat was not a factor involved.

Hibernation has an effect upon the latent response to irradiation. The effect is not clear cut. Some marmots lived longer when irradiated during hibernation than controls which were not hibernating. However, even hibernating animals irradiated with 650 to 800 r died within 14 days with characteristic blood changes (Smith and Grenan, 1951).

8. Biochemical Changes

Only a few of the biochemical changes will be mentioned to show the possible ramifications. The effects on pure or simplified systems, for example, are not to be discussed. An understanding of the biochemistry of the irradiation injury is the best hope for a rational and effective approach for the alleviation of the radiation injuries. So far, with some few exceptions, these hopes have not been realized. The studies made with the changes in enzymes and enzyme systems should hold considerable promise but to date little has been accomplished. Feinstein (1956) has expressed the opinion that, with rare exceptions, increases and decreases in enzyme activity in irradiated animals are artifacts. It must be emphasized, however, that any biochemical alteration must, in the final analysis, be associated with changes in enzymes, coenzymes, substrate, or habitat. Therefore, the efforts in this field must continue in spite of the present lack of success.

It is only the in vivo studies which clearly point out that there are enzyme system disturbances following irradiation. For example, in spite of an apparent radioresistance the functioning of the liver in carbohydrate metabolism is quickly altered. In a series of papers Lourau-Pitres and Lartigue (Lourau and Lartigue, 1950a, 1950b, 1951a, 1951b, 1952; Lourau-Pitres, 1955) show that, shortly after total body irradiation, there is a striking elevation of blood glucose. This is eventually corrected by glycogenesis and not by loss via the urine ro by catabolism. Irradiation did not alter the laydown of glucose as glycogen but there

STATEMENT OF K. H. LARSON,[1] CHIEF, ENVIRONMENTAL RADIATION DIVISION, THE UNIVERSITY OF CALIFORNIA

Dr. LARSON. Thank you, sir.

Gentlemen, it is indeed encouraging to note the progress that has been made with respect to this very complex problem of environmental contamination. From 1946 to 1959, only a few of us were in this field of research of radiation ecology. Since then, much has been learned. However, as in the case of any field of research, many previously unrecognized problems are now ready for the effort available for their solutions. These and previous hearings by this subcommittee will contribute to the forthcoming answers.

With your permission, Mr. Chairman, I submit my prepared formal statement for the record.

Representative PRICE. Very well.

Dr. LARSON. I would like to spend the time allotted discussing certain highlights of the data and observations that we have made since.

During the last decade the environmental radiation division has been involved in progressively intensified programs designed to answer one principal question, viz, "How much manmade radioactivity distributed in the environment can be tolerated safely by man and his economy?"

The more specific objectives of our effort within this broad context include:

1. Delineation of fallout patterns and their characteristics with respect to particle size through which the mechanics of fallout can be more accurately defined. This, in turn, leads to a comparison of the effects of the yield of device detonated, type of device support, and the relation of the detonated device to ground surfaces upon the resultant fallout radiation intensity including the residual radioactivity per unit surface area within the fallout pattern.

2. A detailed study of the chemical, physical, and radiological characteristics of fallout debris relative to its particle size and occurrence within the fallout pattern.

3. Determination of the biological availability, rate of accumulation, and retention of the fallout debris in various native and domestic plants and animals, as well as the persistence and redistribution of residual contamination in the total environment.

The data to be presented are not directly applicable to the problems resulting from nuclear war primarily because continental testing has been limited to low yield devices. Further, tests have not been

[1] Date and place of birth: May 7, 1915, Epworth, N. Dak. Education: B.S., University of North Dakota, 1937; M.S., University of North Dakota, 1939; graduate work, University of California, 1947–58. Work history: Chief chemist, director of research, director of engineering, development and chemical research, North Dakota Mill & Elevator, Grand Forks, N. Dak., 1939–44; Tests Able and Baker, Operations Crossroad, Bikini bomb tests, 1946; chemist, Crocker Radiation Laboratory, University of California, Berkeley, 1946–48; chief, radiochemistry unit, atomic energy project, University of California, Los Angeles, 1948; acting chief of Alamogordo section, atomic energy project, University of California, Los Angeles, 1949; chief, Alamogordo section; field director, Nevada test site fallout group, atomic energy project, University of California, Los Angeles, 1951; chief, radioecology division; director, program 37, Nevada test site, atomic energy project, University of California, Los Angeles, 1952; chief, environmental radiation division; adviser, environmental radiation, Division of Biology and Medicine, U.S. Atomic Energy Commission; director of radioecological and fallout phenomenology studies (program 37), Nevada test site, department and laboratories of nuclear medicine and radiation biology, University of California, Los Angeles, 1957–present; associate in biophysics, department of biophysics, School of Medicine, University of California, Los Angeles, 1958–present.

to the t to the minus 1.2 relationship. A dose-rate decline with time according to the Plumbbob gamma decay (PGD) curve yields calculated doses which are 1.5 to 2 times greater than those calculated by the t to the minus 1.2 relationship from different fallout times to approximately 400 days after shot.

Deposition of radiostrontium in areas adjacent to Nevada Test Site: A balloon-mounted detonation, whose fireball intersected the soil surface, deposited approximately 0.13 percent of the total amount of Sr 89 produced within the area limits defined previously. Two balloon-mounted detonations, whose fireballs did not intersect the soil surface, deposited 0.004 and 0.008 percent within the above perimeters of the total amount of Sr 89 produced. Tower-mounted detonations deposited from 0.5 to 2 percent of the Sr 89 produced and from 1.6 to 7.2 percent of the total amount of Sr. 90 produced.

This means, then, that of the strontium produced by the detonations at Nevada, less than 10 percent remains within 200 miles. The 90 percent is somewhere else, perhaps, in the United States, or circling the world.

This fractionation of strontium 89 and strontium 90 with regard to particle size may be predicted on the basis of the different half-lives of their noble gas precursors, krypton 89 and krypton 90, and the physics and the chemistry of the particle formation.

Biological availability is the next section of my discussion this afternoon. And I will limit our figures, our statements, to that which we have observed out to 400 miles from NTS.

In the undisturbed areas, the radioactive debris from fallout is confined to the surface 2 inches of the soil profile even after 9 years following fallout contamination.

This particular statement is based on the observation at Alamogordo, N. Mex.

Representative HOLIFIELD (presiding). This is an area which has very little rainfall. This would not be true in an area that has considerable rainfall, would it?

Dr. LARSON. This area has between 8 and 9 inches annual rainfall.

Representative HOLIFIELD. That is very little in comparison to the average. I imagine we will have close to 50 inches here in Washington.

Dr. LARSON. That is right.

In agricultural areas under cultivation, the distribution of activity is found down to depths of 4 to 8 inches, due to plowing, harrowing, and other farm practices. Laboratory soil leaching experiments using the equivalent of 84 inches of water translocated the surface activity only about a half inch in the soil column.

Representative HOLIFIELD. That is the answer right there, then. Apparently even in areas where you have up to 84 inches, you only displace it about a half inch.

Dr. LARSON. That is right.

Surface-deposited fallout tends to become mechanically trapped in the soil environment. The amount that is redistributed declines with time. Natural disturbance, however, causes material to be redistributed at levels approximating the initial contamination of medium and long-lived fission products.

Particles 44 to 88 microns in diameter contributed an average of 9.7 percent of the total redistributed fallout following Priscilla (balloon) as compared to 21 percent following Smoky (tower) of the Plumbbob test series. Particles less than 44 microns in diameter contributed an average of 85.8 percent following Priscilla compared to 68.3 percent following Smoky.

During the Plumbbob test series, it was found that the gamma radioactive decay measured in the field was similar to the decay of comparable fallout samples measured in the laboratory. Also, the aerosol concentrations were similar following both Priscilla and Smoky despite significant differences in initial contamination.

Forage plants are recontaminated due to redistribution of selected particulates. This provides a continuous source of internal emitters to grazing animals, and a persistent low radiation field which is dependent on the changing proportions of medium to long-lived fission products. During the Teapot and Plumbbob test series, it was found that the principal source of activity found on forage plants is due to particulate fallout in the less than 44 micron size fraction, that is, vegetation within fallout patterns out to 300 miles from Nevada Test Site is a "selective" particulate collector. The number of particles retained by the foliage is dependent upon its characteristics, such as hairs, glands, and other mechanical traps.

The fallout contamination of native plant material persisted through the 18-day period following both Priscilla and Smoky detonations, the only change being that due to radioactive decay.

A negligible fraction of the total contamination of the soil by fallout debris from tower supported detonations was accumulated through the root systems of native forage crops and alfalfa and so on.

One of our principal biological indicators in our fallout studies is the kangaroo rat. This is an example of one of the animals that we have. Another one is the antelope ground squirrel. These animals are abundant in any areas that we would care to work.

During the 1955 test series the concentration of radioiodine 131 in the thyroids of rabbits and other native rodents was found to be a fuction of distance. The maximum concentrations were found at approximately 60 miles. This maximum concentration was a factor of two to seven times higher than that documented at 20 miles or at 160 miles. Twelve months after the Upshot-Knothole series, accumulation of radiostrontium was also found to be a function of distance, with the maximum bone concentrations in rabbits at 130 miles along previously documented fallout patterns.

Six months after the Teapot series in 1955, again, the radiostrontium in the bones of the jackrabbits was found to be a maximum at 130 miles. This was five times higher than either at 30 miles or at 400 miles.

Of the several fission products accumulated in bone, 12.5 to 40 percent was accounted for in terms of radiobarium and radiostrontium by D plus 20 days.

Maximum tissue accumulation of biologically available fission products occurs at locations corresponding to fallout times of H plus 2 to H plus 3 hours. Fission product concentrations then decreased with increasing time of fallout. In the single balloon supported detonation studied, the decrease was constant between locations corresponding to H plus 2 to H plus 12 hours. In tower supported detonations, however, biologically available fission product concentration tended to be uniform over distances corresponding to H plus 5 to H plus 14 hours.

For any given location the relative tissue accumulation of biologically available fission products resulting from Priscilla and Smoky fallout contamination was similar with the maximum values occurring by D plus 7 days.

Biological hot spots were identified geographically in the Boltzmann (78 miles from Ground Zero), Diablo (60 miles from Ground Zero), Smoky (70 miles from Ground Zero), and Shasta (172 miles from Ground Zero) patterns.

This concludes my statement, sir.

Representative HOLIFIELD. Thank you.

Your prepared statement will appear in the record in full.

(The statement referred to follows:)

solubility of fallout material in water and 0.1 N hydrochloric acid (HCl).

The fallout material from balloon-supported detonations was more soluble in both water and acid than that produced by other types of detonation. The solubility of fallout from tower-supported detonations increased with decreasing particle size. However, in the case of balloon-supported detonations, the smaller particles were somewhat less soluble than larger particles.

	Fallout Material from: Tower shots	Fallout Material from: Balloon shots
	MAINLY SOIL SILICON (GLASS!)	IRON OXIDES FROM BOMB
Water solubility expressed as per cent total beta activity:		
greater than 44 micron fraction	< 1%	31%
less than 44 micron fraction	< 2	14
0.1 N HCl solubility expressed as per cent of total beta activity:		
greater than 44 micron fraction	5	> 90
less than 44 micron fraction	14 to 36	> 60

FUSED SILICATE SOIL FALLOUT:

It should be noted that fallout from the underground shot, Jangle Series (1951) had a solubility greater than tower-mounted detonations but less than balloon-mounted detonations for the particle range of less than 44 microns. It was 5.4 per cent soluble in water and 25 per cent soluble in 0.1 N HCl.

5. Radiochemical Properties of Fallout Materials: Fallout particles less than 44 microns had greater percentages of radiostrontium and radio-

Table 1 EFFECT OF PLOWING.

Sr90 Levels by Fusion Analysis at Eleven Selected Areas in Nevada and Utah

Date of Collection, August, 1958

Area	Location	Sr90 Activity (0 - 1" Depth) mc/sq mi	Sr90 Activity (0 - 1" Depth) μμc/g Ca
Cultivated Agricultural Areas			
Alamo, Nevada	1 mi S	21.3	6.8
Moapa, Nevada	7.7 mi NW	16.3	2.5
Riverside, Nevada	0.4 mi S	22.7	9.6
St. George, Utah	1 mi SE	14.4	4.5
Hurricane, Utah	1 mi SW	12.4	3.5
Enterprise, Utah	0.7 mi N	7.46	8.6
Cedar City, Utah	2 mi SW of Enoch	16.7	4.6
Vernal, Utah	4 mi S	13.8	8.7
Virgin Undisturbed Area, Fallout Midline Locations			
Moapa, Nevada	8 mi N	142	38.3
Elgin, Nevada	3.8 mi SW	114	140
St. George, Utah	5 mi N	45.6	406
Enterprise, Utah	9 mi N	41.2	51.2
Panguitch, Utah	City limit, NW corner	31.9	14.9
Sunnyside, Utah	3.1 mi S of Columbia, Utah	67.2	202

SOIL DECONTAMINATION:

in the chemical composition of the soils as the organic matter decomposed.

The addition of lime ($CaCO_3$) and gypsum ($CaSO_4$) to acidic soils low in native Ca reduced Sr^{90} uptake by plants. Greatest inhibition occurred at treatment levels equivalent to from 2 to 5 tons per acre. At these levels $CaCO_3$ reduced Sr^{90} uptake about 60 per cent; $CaSO_4$ caused an 80 per cent reduction. These Ca amendments to the soil had little or no influence on the uptake of Sr^{90} from neutral and alkaline soils.

The uptake of Cs^{137} occurring as a contaminant increased as the K concentration in the soil was reduced by prolonged cropping. The addition of K to contaminated soils low in potassium content reduced the uptake of Cs^{137} by plants.

These radioecological studies have clearly revealed that (1) biological effect (or hazard) cannot be realistically assessed on the basis of measurement of only the gamma radiation field. Fission products from radioactive debris produced by man can be assimilated by animals with the maximum degree of accumulation not necessarily near the source of the nuclear reaction. Further, within a distance of 400 miles from the Nevada Test Site, the plant foliage is a selective particle collector. There has been no significant accumulation of activity through the root system. (2) Biological availability of fallout debris is strongly influenced by the conditions of contamination and by the physical and chemical nature of the contaminating material and its interaction with environmental factors. (3) Within 200 miles from the Nevada Test Site Sr^{89} and Sr^{90} are estimated to be less than 10 per cent of the total theoretical Sr^{89} and Sr^{90} generated by all detonations at the Nevada Test Site since the Ranger Test Series.

FRACTIONATION OF SR89/90 IN LOCAL FALLOUT

STATEMENT OF JOHN N. WOLFE,[1] CHIEF, ENVIRONMENTAL SCIENCES BRANCH, DIVISION OF BIOLOGY AND MEDICINE, U.S. ATOMIC ENERGY COMMISSION

Dr. WOLFE. Mr. Chairman and members of the committee, it is a rather considerable privilege to appear before your group, because I may be perhaps the only ecologist that has ever been in here, although you have received a considerable amount of ecological testimony from time to time.

Representative DURHAM. I think you are the first.

Dr. WOLFE. I do not know whether any of the other witnesses would want to be called ecologists.

What I have to talk about is the long-time effects of nuclear war. And ecologically, this is very difficult to assess.

In the first place, I am talking in terms of broad general landscape processes, such as erosion, fire, and all the other processes that go to make the landscape. In the second place, I am talking about things for which we have no experimental data.

Our detonations, first of all, were on the desert, and if I remember the map not many of your devices will be dropped on the desert. In the second place, where we have the opportunity to study the biology of a region or an area most significantly from a human relations viewpoint there have been no nuclear detonations, that is, in any humid region, such as the deciduous forest region of eastern North America.

In the third place, there has never been an opportunity to totally survey, from a biological point of view, a landscape or a seascape prior to a detonation.

Our evaluations have had, therefore, to come from the studies afterward, not knowing what ground zero is biologically.

Therefore, it is only possible to paint a picture in broad strokes. Perhaps it is only possible to raise questions that would put us in some perspective as to the kinds of things that we would be concerned with.

Vicissitudes of the environment and long-time processes such as mountain building, erosion, emergence, and submergence of the land, fire, climatic fluctuations, and glaciation, have all played a role in the history of the biota of this continent. Included in that list would be vulcanisms (volcanoes). And life has managed to survive.

It therefore would appear to me that even in any kind of nuclear war, there would be survival of life. And what the condition of man would be, I am not able to predict, and leave that for others. But there would not be complete obliteration. Even in local areas, there would be readvancement of living things.

I think that even the radiation effects which have been described here by more competent people than I am in this field, as in the past, would perhaps result in the survival of the fittest, the elimination of

---

[1] Date of birth: Dec. 2, 1910, Logan, Hocking County, Ohio. Education: B.A. 1933, M. Sc. 1934, Ph. D. 1937, the Ohio State University. Experience: Instructor, Ohio State University, 1937–43, ecological research and teaching freshman botany, floristics, field ecology; assistant professor, 1944–47; associate professor, 1948–53; research in vegetation, vegetational history, bioclimatology; graduate student program in ecology (8 Ph. D.'s, 13 M. Sc.'s); teaching plant ecology, botanical exploration in Mexico, Greenland, and eastern North America. Professor, 1954—; ecologist, division of biology and medicine, U.S. Atomic Energy Commission, 1955–56. At Ohio State University, 1957. Affiliations: Ecological Society of America, Botanical Society of America, Sigma Xi, American Association for the Advancement of Science, American Institute of Biological Sciences, associate editor (Ecological Monographs), "American Men of Science."

That would be my judgment on it, and I am certainly not equipped professionally to substantiate that, except from the volumes of testimony.

Dr. WOLFE. I thought I would have less trouble with that statement than any of the ones I have made. You can strike that one out. The principle is more important.

Representative HOSMER. It might be our confusion on the point where somebody had been exposed to radiation, that it is like a disease, to be passed on. That is simply not true. You do not have to be worried about someone catching radiation from one who has been exposed.

Dr. WOLFE. I did not mean to imply that.

Representative HOLIFIELD. Proceed, Doctor.

Dr. WOLFE. I visualize those people unsheltered in heavy fallout areas after 3 months, to be dead, dying, sick, or helpless; those sheltered, if they can psychologically withstand confinement for that period, to emerge to a strange landscape. The sun will shine through a dust-laden atmosphere, the landscape in mid-January would be snow-covered or blackened by fire in a mosaic. I do not mean it will be snow or black. There would be a mosaic of burned areas.

At higher latitudes blizzards and subzero temperatures would add death and discomfort; both food and shelter would be inadequate and production incapacitated.

In Dr. Reitemeier's remarks, he seemed to think that the harvest would mostly be over and the foodstuffs put away. As I gather, this attack is not going to be announced, if it becomes reality, and a lot of food would not be put away, and would be lost by fire.

Representative HOLIFIELD. I think he was depending on the time of the year. October 18th is a date by which much of the hay and wheat and barley and oats have been harvested. That was his reference to that. Any left out in the open would be subject to fire and contamination, certainly, even though it had been harvested, if it were in stacks.

Dr. WOLFE. It was a minor point.

Representative HOLIFIELD. But I think your reference there to "the sun will shine through a dust-laden atmosphere" is very correct. And I am going to ask Colonel Lunger to state what happened in the Mike shot.

You were there, Colonel Lunger, and participated in that test.

Colonel LUNGER. I think the chairman is referring to the time when we detonated the first thermonuclear device. I can remember very clearly we fired from afloat, it was the first time in the history of test operations that we had to go afloat. We shot early in the morning and the entire task force was steaming north and south trying to keep out from under the local fallout. Late in the evening of shot day I remember we were in the ward room getting our first hot meal, and they came down and told us there was a phenomenon on deck we should see. It was just about sundown. We got on deck, and there was an amber glow along the entire horizon. It was the most artificial thing I have ever seen and sensed in my life. We had displaced many millions of tons of coral debris that had been lifted up to forty and fifty thousand feet by the blast. The crater formed by the detonation was approximately 185 feet deep by a mile and a

quarter across. You can visualize the displacement. This phenomenon was caused by the diffusion of light through the particles in the atmosphere. Keep in mind too it was a detonation of only about 10 megatons.

So the picture that Dr. Wolfe has presented here is very real. When you multiply this phenomenon I have described by approximately 200 weapons in this hypothetical attack, it would be a psychologically unreal world for quite a period after the attack.

Dr. WOLFE. I thought somebody would disagree with that.

Representative HOLIFIELD. Well, you see, you were nearer right than you thought.

Dr. WOLFE. I told you at the start that this was difficult of assessment.

Come then spring floods, and soon after, adding measurably to the disrupted pattern of human existence, are the weather events such as hurricane and tornado, for which there is no defense, and after which there will be little aid.

Perhaps we have dwelled too long on the immediate effects, but it is these that trigger the longtime processes that result in environmental changes of long duration—and therefore changes in the biotic composition of communities that can live under these changed conditions.

But as I suggested at the outset, long-term ecological effects of nuclear war are difficult to assess, however, with the advent of that first spring, I would assume the beginnings of a gradual return to equilibrium of the biological environment. I would anticipate that in springs and summers in the decades that follow biotic succession would continue, leading to full ecological recovery.

The role of North American man in this long-term view of environment—his nationality, genetic constitution, psychological makeup, and creative potential, 3, 10, or 100 generations later, I leave for others to predict.

Representative HOLIFIELD. Thank you very much.

This was our last witness for today. The morning session tomorrow will be opened with a presentation of detailed casualty estimates by target area. Testimony will be given by Mr. Eugene Quindlen of the Office of Civil and Defense Mobilization.

Dr. Willard Libby, Commissioner of the Atomic Energy Commission, will discuss emergency protection measures.

Mr. Herman Kahn of the Institute of International Studies of Princeton University will make a presentation on the major implications of these hearings.

And following this, a panel, the members of which will be announced later, will discuss these implications. That will close the hearings.

The meeting is adjourned.

(Dr. Wolfe's prepared statement follows:)

LONGTIME ECOLOGICAL EFFECTS OF NUCLEAR WAR

John N. Wolfe, Chief, Environmental Science Branch, Division of Biology and Medicine, U.S. Atomic Energy Commission

ABSTRACT

The longtime ecological effects of nuclear war are nearly impossible to assess and even difficult to speculate about. One can only think in terms of major

ecological factors that would be intensified or triggered, and follow the chain of cause and effect to some plausible ultimate set of environmental conditions. Rather than a catalog of effects, only a general picture can be painted, and that in broad strokes.

The obliteration of life in all its forms in continental areas is almost inconceivable and the ultimate recovery of the landscape would be certain in some pattern, probably not unlike the primeval distributions of forest, woodland, desert, and grassland on this continent.

Let us begin with the impressive facts that life in North America and in the adjacent seas has undergone a considerable array of environmental changes since biotic beginnings. Submergence and emergence of the land masses, erosion to base level, mountainbuilding, multiple climatic fluctuations, glaciation, not to mention invasion by the Europeans are major examples. All of these processes are still in operation.

Nuclear war, as it is possible for me to visualize it within my limitations, would scarcely match the effects of these processes on life in the total picture—although landscape recovery in some areas might be in terms of decades or centuries.

Even radiation effects on genetic systems might be considered in the long run to result in only the elimination of the unfit—i.e., the organisms (biotypes) unfit for the environment brought about by this kind of environmental modifications.

However, omitting consideration of radiation for the present, widespread damage due to the thermal and blast components of the bomb would occur in many kinds of biotic systems.

Fire, for example in the dry season of mid-October, would spread over enormous areas of dry western coniferous forests and in the grasslands, with concomitant destruction of natural living resources and their habitats. It is most likely, in my opinion, that these fires would go unchecked until quenched by the winter snows, spreading over hundreds of thousands of square miles. In eastern United States, the dry oak and pine forests of the Blue Ridge and Appalachians from New England to Virginia, adjacent to multiple detonations, would undergo a like fate, as well as the pine on the southern Atlantic and Gulf Coastal Plains. In the agricultural land of the Mississippi Valley, with the crops harvested, fire is likely to be more local, less severe, but widespread. Add to this denuding effects of radiation and/or chemically toxic materials.

With the coming of spring thaws, especially in the mountains, melt water from the mountain glaciers and snowfields would erode the denuded slopes, flood the valleys, in time rendering them uninhabitable and unexploitable for decades or longer. Removal of the turf by fire and erosion on plains and prairie would result in uncheckable erosion by wind, with subsequent expansion of present "dust bowls" and creation of new ones of wide extent. Emergency overgrazing, and cultivation (if there were those to work) would wreak further havoc.

This seems a simple concept but the effects are indescribable in their immediate implications, almost incalculable in their lingering results before ecological processes attain ascendancy and begin the long march back to equilibrium. It would be almost ludicrous to assess present losses of natural living resources resulting from cigarette butts and camp fires against those that would be generated by surface-detonated nuclear devices, the latter augmented by absence of any effort of control.

Along with fire, flood, and erosion, which would also decrease productivity of the landscape or render it inaccessible to people in uncontaminated refugia, would come intensification of disease, plant and animal, including man. Moreover, in the less irradiated areas, populations of deleterious animals, especially insects, would move in—a further detriment to food production and contributing further to its unavailability to surviving people.

Man's access to succor through hospitalization, treatment, communications, etc., would be meager, and thus the inroads of starvation would be accentuated by increased incidence and intensity of disease.

The immediate physical effects (other than radiation) could be particularly catastrophic in such areas as the Los Angeles watershed, where the city is almost surrounded by vegetation susceptible to the inroads of fire. Those islands relatively free of radioactivity in the early stages would be increasingly contaminated as well by redistribution of radioactive materials by wind, water, biotic migration, and precipitation. Radiation effects are more adequately described elsewhere,

but it seems necessary to point out that in a dynamic environment, no area can be regarded as completely isolated from contamination. Indeed animals that are able to move into the "clean" areas will be contaminated survivors from adjacent areas, and probably (both wild and domesticated) will be unfit for human food.

I visualize those people unsheltered in heavy fallout areas after three months, to be dead, dying, sick, or helpless those sheltered, if they can psychologically withstand confinement for that period to emerge to a strange landscape. The sun will shine through a dust-laden atmosphere, the landscape in mid-January would be snow-covered or blackened by fire; at higher latitudes blizzards and subzero temperatures would add death and discomfort; both food and shelter would be inadequate and production incapacitated. Come then spring floods, and soon after, adding measurably to the disrupted pattern of human existence, are the weather events such as hurricane and tornado, for which there is no defense, and after which there will be little aid.

Perhaps we have dwelled too long on the immediate effects, but it is these that trigger the long-time processes that result in environmental changes of long duration and therefore changes in the biotic composition of communities that can live under these changed conditions.

But as I suggested at the outset, long-term ecological effects of nuclear war are difficult to assess, however, with the advent of that first spring, I would assume the beginnings of a gradual return to equilibrium of the biological environment. I would anticipate that in springs and summers in the decades that follow biotic succession would continue, leading to full ecological recovery.

The role of North American man in this long-term view of environment—his nationality, genetic constitution, psychological makeup, and creative potential, 3, 10, or 100 generations later, I leave for others to predict.

(Whereupon, at 4:40 p.m., Thursday, June 25, 1959, the hearing was adjourned, to reconvene Friday, June 26, 1959, at 10 a.m.)

TABLE 1.—*Effects on individual metropolitan areas*—Continued

[In thousands]

Target area and weapons	Number of people in attacked areas [1]	Number killed 1st day	Number fatally injured	Number surviving injured
1 3-, 1 1-megaton weapon each:				
Bridgeport	504	105	84	54
Canton	283	84	59	42
Chattanooga	246	85	77	29
Davenport	234	73	53	53
Erie	219	54	42	42
Flint	271	77	46	39
Grand Rapids	287	124	66	21
Knoxville	337	112	106	38
Lancaster	235	54	51	49
New Haven (Waterbury)	546	192	138	95
Peoria	250	84	54	28
Reading	256	72	66	60
South Bend	205	84	53	34
Syracuse	342	89	68	73
Trenton	230	41	80	97
Utica-Rome	284	107	60	2
Wheeling	355	59	58	46
Wichita	222	78	75	38
Wilmington	269	77	76	67
Worcester	547	128	151	97
Subtotal	6, 122	1, 779	1, 463	1, 004
1 1-megaton weapon each:				
Binghamton	185	58	32	17
Evansville	161	60	34	23
Fort Wayne	184	69	41	23
Greensboro	191	28	19	32
New Britain (included with Hartford).				
Rockford	152	42	25	25
Waterbury (included with New Haven).				
York	203	46	31	17
Subtotal	1, 076	303	182	137
City target area total	68, 460	18, 556	16, 825	11, 009
Nontarget area total	82, 239	1, 095	5, 354	6, 182
Grand total	150, 699	19, 651	22, 179	17, 191

[1] 1950 population figures.

13% 15% 11%

Representative HOLIFIELD. In the case of those fatally injured, did you compute the time between injury and death?

Mr. QUINDLEN. These would be those dying within 60 days, sir.

The number killed the first day was by far the heaviest in New York City with 3,364,000 killed in the first 24-hour period and an additional 2,634,000 fatally injured. Chicago, on the other hand, had 545,000 killed and 447,000 fatally injured.

There is a very important point here which I want to emphasize and I will use this second table to do it. This attack resulted in considerable variation from city to city. In Boston, for example, 75 percent of the persons living in the area were killed, while in Chicago the figure was only 18 percent. In Chicago about 70 percent of the people were not injured at all and an additional 12 percent were injured but will survive. Let us look at Los Angeles. Sixty-five percent of the people in the area would eventually die from this attack, but most of these would not die immediately. This is a substantially different picture from that for some of the other large cities.

TABLE 2.—*Comparison of attack effects on 12 largest metropolitan areas*

Target area and weapons	Percent killed first day	Percent fatally injured	Percent surviving injured	Percent uninjured
2 10-megaton weapons each:				
Boston	37	38	16	9
Chicago	10	8	12	70
Detroit	27	20	18	35
Los Angeles	16	49	19	16
New York City	27	20	18	35
Philadelphia	35	27	21	17
1 10- 1 8-megaton weapons each:				
Baltimore	44	35	13	8
Cleveland	27	20	22	21
Pittsburgh	27	30	2	41
St. Louis	44	29	12	15
San Francisco	33	34	13	20
Washington, D.C	39	30	16	15
Total	27	26	16	31

Mr. QUINDLEN. Going down to the second group of cities, we notice that Cleveland did not sustain, for example, nearly as devastating an attack as did Baltimore. The point we should emphasize here is that this is the result for this particular attack with these weapons on this day, which happens to be a typical mid-October day. A variation even in wind patterns could affect these casualty figures. A different attack pattern, the failure of enemy aircraft, interceptions by our active defenses and many other factors could result in an individual city being spared or being less heavily damaged than this material indicates.

Representative DURHAM. What are some of the reasons for that differential? Could you be specific?

Mr. QUINDLEN. The reason primarily is that in any delivery of this sort, in any attack by air or by missile, there are many chance factors—the question of whether particular aircraft keep running during the attack, whether there is engine failure, the effect of our active defenses, and this matter of random bombing error.

Representative DURHAM. Did you try to calculate it on the basis of our active defense against these missiles?

Mr. QUINDLEN. No, sir. We did not. But we do want to make the point that if we took this attack pattern and had a different wind pattern along, or we applied a second time the random bombing error, a weapon which landed on the north side of a city might land on the south side of a city, and this could result in a different number of deaths and a different number of injuries.

Representative PRICE. I think you told the chairman you are going to be specific, now, on why the situation at Chicago is as you computed in your table, here. In other words, you have been general about what could affect the situation. But in your computation, what did you do as to the basis for the difference?

Mr. QUINDLEN. I will give you the specific information, Mr. Price, as to where the Chicago weapon landed as compared to where the New York weapons landed.

Representative HOLIFIELD. I can understand your reasoning, that there would be different effects if there were different wind paths. But I would like for Colonel Lunger to question you on some of the things you have said. It seems to me some things need clarification.

have made an honest and earnest attempt to be responsive to the committee's request. Such variables as do exist in these formulas, and in the differences in population—are understandable. This can be taken into consideration by people who wish to pare this down to finer detail.

(The following statement was subsequently submitted by Mr. Quindlen:)

I. Method of Casualty Computation in NDAC Damage Assessment Program

In computing casualties from a hypothetical nuclear attack on the United States, the National Damage Assessment Center computer program assigns each person in the Nation to one of a set of standard locations.[1] These standard locations vary in size from census tracts only a few blocks long in the large cities, through minor civil divisions in the suburbs, to whole counties in sparsely settled areas. To make the computation manageable, even with a high-speed computer, it is necessary to suppose that the entire population of each standard location is concentrated at a central point. Since the standard locations are small in the densely populated areas, this generalization is not regarded as a source of significant error.

Computation of the casualty percentage from direct effects (blast thermal, and direct radiation) is based on the distance from the center of the standard location to the nearest ground zero. The distance associated with a given casualty probability is scaled according to the cube root of the yield.[2] The case where several weapons affect a standard location is handled by applying the largest of the casualty probability percentages caused by any of those weapons. The casualty percentage tables are based on the Hiroshima-Nagasaki data.[3] Percentages of mortalities and of nonmortal casualties are computed. EXAGGERATION!!

Another phase of the program computes the probable fallout dose at points on the map chosen so that no standard location is more than a mile and a half from a reading. The locations and yields of the weapons and the speed and direction of the winds are taken into account. The basic pattern of fallout distribution is taken to be a semicircle upwind and a half an ellipse downwind, with slight distortion from the effect of wind shear at low wind speeds. The downwind distance is scaled directly with the speed of the wind, and the amount of radioactive material is kept constant by dividing the dose rates by this wind scaling factor. Thus as wind speeds increase the contours grow longer and narrower, and the maximum dose rate in the pattern is reduced. For weapons of different yields, the size of the pattern is scaled according to cloud diameters.[4] This fallout contour model was developed with the advice and assistance of Dr. Lester Machta and Mr. Leo Quenneville, the special projects branch of the U.S. Weather Bureau. The lengths and areas of the contours, and hence the amount of radioactive material distributed, are those developed by the Physical Vulnerability Division, Director of Targets, Assistant Chief of Staff, Intelligence, Headquarters U.S. Air Force.[5] The doses from all weapons near enough to affect a point are added together.

The percentages of the population killed and made ill by the fallout dose are computed, taking into account the shielding of the homes, basements, and other places where the people might take cover.[6] The table of residual factors and poplulation distribution used in the June 3, 1959, computations for the Holifield committee were based on estimates by Mr. Gallagher and Mr. Horton of OCDM of the best protection that might be afforded by moving people into the available structures offering the best protection from radiation. The fallout casualty percentage are computed from the effective biological dose, a concept taking

[1] "National Location Code." Prepared for Federal Civil Defense Administration by Stanford Research Institute. January 1956.

[2] "The Effects of Nuclear Weapons." Department of the Army Pamphlet No. 39-3. May 1957; p. 96.

[3] "Vulnerability Functions for Civil Defense Damage Assessment Program." Prepared for Federal Civil Defense Administration by Stanford Research Institute. April 1956; pp. 5, 7, 16–20. Secret.

[4] "Close-in Fallout." W. W. Kellogg, R. R. Rapp, and S. M. Greenfield. Journal of Meteorology. February 1957.

[5] "Nuclear Weapons Employment Handbook." Air Force Manual 200-8. HQUSAF; pp. 101–108.

[6] "Effects of Nuclear Weapons," pp. 470–477. "Nuclear Weapons Employment Handbook," p. 125.

into account the ability of the body to recover from some of the radiation to which it is exposed. This dose was defined by a committee of leading radiologists meeting under OCDM auspices on February 20, 1959.

The direct effects mortalities are computed first, then the fallout mortality rate is applied to those surviving. In this way the program avoids counting the same fatality twice. The same procedure is then followed for the nonmortal casualties from direct effects and from fallout.

II.—The second question related to the average radiation dose to D+90 days. The average for all survivors was 110 roentgens, while the average for noninjured survivors was 60 roentgens.

Representative DURHAM. Mr. Chairman, I want to express my appreciation, and I think the country at large should appreciate the fine work you people have done in trying to educate the public.

I would like to ask whether or not we should continue to do something like this on a yearly basis, to try to further bring to the public the important thing that we face. Do you think it should be done annually, semiannually, or how often?

Mr. QUINDLEN. Sir, I think that the people of the United States certainly at least annually would benefit by having the attention of the Senate and the House of Representatives devoted to this as a recognition of the importance and of the facts of life which are here present; and that this is not a scare business but that this is a realistic problem to which all of us must devote a good amount of attention.

Representative DURHAM. That is exactly what this committee has endeavored to do from the beginnings of the first radiation hearings all the way through, to put the facts in print so that the people can know what is before them.

Representative HOLIFIELD. Mr. Quindlen, many of the members of this committee, all of them I would say, have borne a very heavy burden of responsibility in carrying figures like these and similar ones in our heads for a long time. Many of us feel it is time for the American people to help bear the burden of responsibility of the kind of world we live in and try to help solve the problems. They are difficult problems. Maybe there are no solutions. But the composite understanding of the American people, it seems to me, is an adequate source of intellectual resource to solve almost any problem, provided we are given an opportunity.

Mr. QUINDLEN. Sir, as I indicated in my first presentation on Monday morning, it is our firm conviction that if the public is fully informed, it will take the necessary action. This has been demonstrated many, many times in our history.

Representative HOLIFIELD. Thank you.

Representative HOLIFIELD. Now, we are going to change our order of witnesses a little.

We have just received a phone call on Dr. Libby's airplane. It is en route between New York City and Washington Airport. So we are going to move up Mr. Herman Kahn, Center of International Studies, Princeton University, who presently is on leave from the Rand Corp. Mr. Kahn is a distinguished lecturer and educator and a student of this problem. He is one of the real experts of the Rand Corp., which has done many studies for the military departments.

If I could get Mr. Kahn not to talk as fast as he usually does, maybe we can follow him.

STATEMENT OF HERMAN KAHN,[1] CENTER OF INTERNATIONAL STUDIES, PRINCETON UNIVERSITY

Mr. KAHN. I will do my best.

Representative HOSMER. I think, Mr. Chairman, that Mr. Kahn and the people who have worked with him have given this subject the closest scrutiny that it has ever been given. I think we are fortunate indeed to have him before us.

Mr. KAHN. Thank you very much.

Representative HOLIFIELD. I notice that you have been here every day. You have seen a congressional committee in action over a long period of time now. I think you have a concept now of the laborious method by which we put things on record.

Mr. KAHN. I am impressed with how fast you do it. We spent a year and a half; and you have covered about the same ground in 4 days of testimony.

Representative HOLIFIELD. You see, you folks are not as expert as the committee.

Mr. KAHN. I would like to make it clear that I am appearing here as an individual. While many of the points I make will be based on work I and my colleagues have done at the Rand Corp. in 1957 and further work done at the university, the formulation, presentation, and opinions are my own. Because of the controversial nature of some of my remarks, it is very important to make this very clear.

I recently had occasion to give three lectures on thermonuclear war in New York City. One member of this committee and several members of the staff attended these lectures. I have been asked to summarize those aspects of the lectures which would be most appropriate to the function of this committee and in light of the testimony that has been heard.

The lectures were long. They took about 7 hours to give and there were about 4 hours of discussion available to amplify the remarks I made. And, on the whole, the audience was an expert audience. The reason for emphasizing these points is that I am going to have to be very light today; some of the things I will say need many qualifications, but for the sake of continuity of discussion and for the sake of just moving along, I will not be able to make all of these qualifica-

[1] Undergraduate work at UCLA., Graduate work at California Institute of Technology. With Rand Corp. for 10 years, November 1958 to present. On leave of absence since January 1959 and now with Center of International Study, Princeton University. Was a consultant to the Gaither Committee; Scientific Advisory Board of the Air Force; Technical Advisory Board, AEC; Office of Civil Defense Mobilization.

tions. This inevitably leads to misunderstandings but given the constraints of time this cannot be helped.

Let me start by making some remarks about quantitative computations. The most important reason for being quantitative is because one may, in fact, be able to calculate what is happening. Many of the witnesses have emphasized the uncertainties of thermonuclear war but if we had raised Napoleon from the dead, and had him listen to these hearings he would have been impressed with the exact opposite notion; he would have been impressed with the relevance of quantitative calculations; impressed with the accuracy with which people predict what a nuclear war is like. One could not have applied the principles of physics, engineering and biology to an Indian war. In other words, when one drops a bomb with a certain yield and CEP one can then say: "These cities will be destroyed, these bases will be put out of commission, and so on with at least moderate reliability. In particular, one can have reasonably good lower estimates of the damage.

This is of some real interest; before World War II, for example, many of the staffs engaged in estimating the effects of bombing overestimated by large amounts. This was one of the main reasons that at the Munich Conference and earlier occasions the British and the French chose appeasement to standing firm or fighting. Incidentally, these staff calculations were more lurid than the worst imaginations of fiction.

In our case, when we say a building falls down, it very likely does. When we say a person is killed with a thousand roentgens, he very likely does die. Our calculations are more likely to be underestimates than overestimates since the effects we have overlooked are obviously not in the calculations. This means that the picture of horror that is painted of a war today is in some sense reliable. It really may happen as described.

On the other hand, one can still overestimate the horror. I would like to associate myself with the spirit of the last witness' testimony in emphasizing the importance of a nation surviving, and of looking at what survives in addition to what is destroyed. I do not like his analogy of the handicapped individual, because that gives the feeling of being crippled for the rest of one's life. One never really recovers from a handicap such as the loss of an arm. One can only adapt to the loss and live with it. This is, in fact, the picture most people have of a thermonuclear war—of a sort of permanent setback, if not a form of annihilation. I also would like to point out this is an expert picture, just as in World War II, but more so. Most of the experts, whose duty it is to plan for wars or who write about the subject, do have a picture of a war which is even more lurid, than that which has been painted in the last 4 or 5 days.

It is because of the enormous impact that the introduction of thermonuclear weapons has had on people's notions of what a war is like, that one has had the extreme, I might say almost 100 percent, dependence on the theory of deterrence. This has been coupled with an unwillingness and an inability, a psychological inability, to analyze what deterrence means. In other words, when one has to depend on something working, one cannot afford to question the underlying assumptions; it would be too disturbing, if one did, too disturbing for ourselves and for our allies, if we raised questions that shook our faith in the notions.

In my testimony today, I am going to comment not only on the testimony given to the committee, but on the expectations raised by this testimony and some of the qualifications that should be made on these expectations that might affect our actions, our allies' actions, and Soviet actions, and equally important, how the various ways in which a war could start would affect the kinds of calculations we make here today. That is, the calculations that have been presented, as has been emphasized, are a sort of average calculation, an average which, in fact, would probably never occur. If one only had to make one calculation, this is the kind one would make, it is the kind we have made in the past. It is worth noting that these calculations are very similar to those the Rand Corp. did about 2 years ago, and that they were made independently. That is, the committee drew up the attack without any reference to what the Rand Corp. had done.

So I am not trying to say that the assumptions are bad ones to use. I am saying they are bad assumptions as far as predicting what will happen in any actual case. Not only in the sense of statistical variation, but in the sense that any particular attack pattern is likely to be drastically different from the one that has been used. It will be either worse, or better. And it is very important to understand when it will be worse and when it will be better.

Representative HOLIFIELD. This has been brought out time and again. This is a study, and we are not saying it will happen this way, and it might be either larger or it might be smaller.

Mr. KAHN. The other reason for using quantitative calculations is because one may want to communicate reasonably accurately. The situation itself may not allow much precision in the analysis. One may literally not be able to predict what will happen, but still have strong feelings about what may happen, and wish to communicate these feelings. It is not very useful in such communication to use words like total destruction, annihilating retaliation, end of civilization, and so on. Such words would be appropriate if the target system were overdestroyed. If one has killed a man by an approximate factor of five, nobody really cares whether it is two or ten. Dead is dead. But as soon as one does not overkill the target system, as soon as in fact half, two-thirds, or three-quarters of the target system survive in a significant way—and I hope to explain what I mean by "in a significant way"—then one must be a little more precise in one's statements. It is true that some of the levels of destruction discussed here are unprecedented. But unprecedented is not unlimited. These are quite different remarks.

I would like now to ask the committee's indulgence to my using a debating trick which I have found very useful in the past to illustrate a very important point.

The reason I have to use a debating trick is very simple. It is difficult in a period of a short hearing, even hearings of 4 days, to get people to take these problems seriously, and to do it one has to trick them a little bit.

Let me give you a history of this debating trick, and you will see exactly what I mean.

I had occasion recently to attent a conference on NATO problems at Princeton University. We had both Europeans and Americans

present. Some of the Europeans raised the question: Would American aid be on the way if the Russians seriously challenged us? Would we live up to our alliance obligations?

Using quantitative statements—particularly if they are presented in a detached and objective manner—has another disadvantage. It sometimes gives an impression of almost incredible callousness. In some ways this may be to the good. If you want a detached and objective analysis, then you probably have to do it in a detached and objective manner. This doesn't, of course, imply that you approve of the subject being analyzed—only that you think it is important to understand it. For example if one says that it is not true that everybody is killed but only 50 million people are, this does not mean that the speaker is implying that 50 million people are a small number, but that 50 million people are much less than 150 million.

Now, one can today get up in front of any audience in the United States and make a remark to the effect that the credibility of the nuclear deterrent as a protection of Europe is diminishing close to the vanishing point and nobody will get angry with you. If you make an almost identical remark to the effect that we may not live up to our alliance obligations, people will throw you out of the room. But the two remarks are, in fact, almost identical, if you think about them a moment. The difference is not that the first is a polite way of saying something which is very awful, but that people refuse to accept the immediate consequences of the things they believe.

Most of the Americans at that conference, particularly those with official responsibilities, were horrified at the European notion. Such thoughts in fact almost do not enter any American's head today and possibly never will. And I should make it clear, I am not predicting that they will. However, it is worthwhile pointing out to Americans that the issue is a serious one, one which must be faced, considered and discussed, and if necessary preparations made. If you are afraid to discuss the issue, you will certainly be afraid to meet the crisis when and if it occurs.

Representative HOLIFIELD. This principle is one which this committee has decided was the correct principle. In other words, if we are living in this kind of world, and if these weapons actually exist in the quantities in which we know them to exist, if the deliverability is what our experts on both sides of the fence say it is, then it is time to face these problems and start discussing them, as you have just said. Start trying to find, or maybe accelerating our effort to find, some solution.

Representative DURHAM. How does that enter into the picture? How would you calculate in figures, so that you would put it into the actual picture of a calculated attack, whether or not we would live up to our obligations when and if war were declared?

Mr. KAHN. That is exactly the question I want to address myself to.

To what extent will these calculations affect policy? And I want to ask this question from three points of view. From the Russian point of view: Would they believe we would live up to these obligations? From the European point of view: Would they believe it from the calculations they would make? From the American point of view: Do we believe we will do it and would we, in fact, do it?

You understand, any two of these questions can be answered yes and the third no, and one still has an unpleasant situation. All three must

be convinced of the right answer, and let me repeat, one does not convince the Europeans or the Russians by being afraid to discuss the matter. Just the opposite. One shakes confidence; if we cannot face even a verbal discussion, we certainly cannot face the real thing.

Even though I believe this, I would not be in favor of raising this question in a public and official record if I did not feel we could do things about the inadequacies of our posture in sufficient time for them to be corrected. In other words, if we had passed a point of no return, I would prefer closing my eyes and just sailing ahead. I do not believe we have passed that point, and that is why I think it is important to discuss the problem.

I am trying to demonstrate that things for which normally there is no price, one can sometimes set a price which one knows is big enough, and another which is not. In other words, one can establish a principle, and after the principle is established, one can then haggle over the price and try to reduce the range of uncertainty.

Representative DURHAM. You mean the price of lives?

Mr. KAHN. In this case we are pricing both lives and honor. Now let me establish the principle, if I can, sir.

Let us assume that the Russians had such a competent retaliatory force, and that our own defense, both active and passive, were so weak, that even if we struck the Russians first, in their retaliatory blow they could kill every single American, all 177 million of us. Now, we know this is not a condition which in fact obtains. They cannot do it. But let us just assume it for the moment. Now let me ask every man in this room to put himself in the place of the President of the United States. Assume that the Russians have done something very horrible, say dropped a bomb on London, on Rome, Paris, Berlin, the worst thing you can imagine, but have not touched the United States. By some mechanism (I will describe some possibilities later if I have the time) the President cannot react immediately. He has 24 hours to think over what he will do; at which point he has to decide whether to press the button and punish the Russians, but in turn accept the extinction of the United States of America. And I mean complete extinction.

Now, if you have 24 hours to think about it, you are not going to think about it in isolation. You are going to call a meeting and talk about it.

I do not know how the President would act, and I do not know how I would act under those circumstances. But I do know that one could not blame the Europeans or the Russians for believing that we would not retaliate. Under the assumptions one just cannot blame them for so believing. And, in fact, it is very doubtful that we would retaliate.

Now, if you believe this, then you have to ask: If that principle is possible, what is the price? Let us now haggle over the price. It is clear that we cannot establish an exact exchange rate between lives and honor, between current and future evils. We cannot say whether the Soviet retaliatory threat would be effective at exactly 5 or 30 or 100 million dead. That cannot be done. But I have discussed this question with a number of Europeans and a number of Americans, and they do have feelings about the subject, and they can communicate their feelings. And I might say their feelings change. That is, in

the first few minutes, if you just ask a man to react, many Europeans will say, "At no price will the Americans retaliate." He thinks it is just a bluff. Many Europeans do. On the other hand, the typical American will say, "We cannot be bluffed or blackmailed at any price."

But if you think about it for a few moments, just 5 or 10, not 5 or 10 days, but 5 or 10 minutes, it soon turns out that your price, if you are an American, tends to be in the 10 to 60 million range. And you get 60 million by a very interesting process.

Representative DURHAM. Do you know any time of history when the Americans were attacked that they have not retaliated?

Mr. KAHN. I know of no such occasion. And I do not believe we would not retaliate today. Not only if they attacked America, but if they attacked Europe. I think we will retaliate. I am not trying to cast doubt on the fact that we might retaliate today. However, I am doubtful that we might retaliate 2 or 5 or maybe 10 years from now, if and when the counterthreat gets worse and we do nothing to meet it. I will cast doubt on that.

Representative HOLIFIELD. Under what two conditions did you say?

Mr. KAHN. I would say that today the threat of a Russian counterattack is not large enough to prevent us from living up to our obligations; I believe that this may not be the case in a relatively short number of years, though I am not willing to say whether this is 2 or 10, but well within the lifespan, prospective lifespan, of every man in this room.

Representative DURHAM. You do believe, Mr. Kahn, that we will live up to our obligations, do you not?

Mr. KAHN. I say we will live up to our obligations in the near future, as of today. I am not at all certain—in fact I rather think the opposite—as to living up to our obligations from 2 to 10 years from now, depending on technological progress, the military and nonmilitary defense programs we have, and the progress the Russians make.

Representative HOLIFIELD. In other words, you are anticipating technological increases which will make complete annihilation of both countries a matter of certainty as far as capability is concerned?

Mr. KAHN. Not complete annihilation. Just a third or a half the country is enough. In fact the attack that has been discussed in this room may be enough. But the attack that has been discussed in this room in the last 4 days is an unrealistic attack for these circumstances. And I will explain later why this is so.

Let me for a moment discuss the opinions of the Americans and the Europeans that I have polled.

The way one gets 60 million casualties as a price one cannot afford to pay is by taking roughly one-third of the population. In other words, I have yet to meet an American who, after he thought about the problem 10 minutes, was willing to sign his name to a statement that he believed the United States would go to war deliberately, in cold blood, on any issue short of a direct attack on the United States, if more than half the people in the United States were killed on the Soviet retaliatory blow. It has to be less than half. Some Americans, as I say, argue that we would be blackmailed into acquiescence if we were threatened with only 10 or 20 million casualties. Those few Europeans I have talked to have a much weaker impression of

American tenacity, American purpose. Their estimates lie between 2 and 20 million. And it is important, you understand, that they have a proper opinion, too. I have no feeling at all what a Russian estimate would run. Absolutely none. I do know it might run very high. The Russians lost something like 10 percent of their population, and, they claim, about one-third of their wealth, in World War II. And they know they recovered from that. While they are still appalled at the damage they suffered, they can think in these large terms. So the Russians might be very impressed with the U.S. capability, and the United States might in fact have both the will and the capability, at a time when the Europeans did not believe it. This is a very possible situation, and in some circumstances, a disastrous situation.

It is important, in other words, to differentiate very sharply between what I have called Type One Deterrence, which is trying to deter a direct attack on the United States, and what I have called Type Two Deterrence, which is trying to deter an extremely provocative action. In the first case, many things enter Russian calculations as to whether they should attack the United States or not. But one of the most important things which will enter their calculations is their estimate of what would happen to Russia if they struck the United States at a time of their choosing and we strike back, with a damaged force, in the teeth of an alerted air defense, and in some instances after the Russians have evacuated their cities.

Type Two Deterrence, deterring extremely provocative actions, involves a quite different calculation. It is again a Russian calculation. Only now the Russian asks himself: If I do this very provocative thing, which is less than a direct attack on the United States, but which is still very provocative, will the Americans start the all-out war? That must be influenced by whether or not the Americans think they can survive our counterattack. And that means the Americans must calculate that they strike first and we Russians strike back with a damage force. Things will be completely reversed from the Type One Deterrence calculations.

I might point out that in both World War I and World War II it was Type Two Deterrence we were talking about. That is, the British declared war on the Germans, and not vice versa.

Representative DURHAM. In those conditions you would not think we would strike back? Is that true, Mr. Kahn?

Mr. KAHN. No, I believe, and I should make this very clear, that if the Russians did something very provocative in Europe today, we would live up to our alliance obligations and strike.

Representative DURHAM. I was thinking about the 6, 8, or 10 years you were talking about.

Mr. KAHN. I believe that under current programs we will not.

Representative HOLIFIELD. Now please define the current programs.

Mr. KAHN. We have certain programs in the field of air and missile offense and air and missile defense, and civil defense. Add them all up, and it is hard to believe that we would be willing, and I do not wish to be specific in years, because this would get us into the classified field, but at some time in the future we will in fact be outbid, under current programs.

Representative HOSMER. That would include the consideration of whatever measures we take over and above what we have at the present time to reduce the effect in our own country of the attack?

Mr. KAHN. That is correct. There are many things to be done in both the civil and military field. I would prefer not getting into that at this time.

Representative HOSMER. You say in plus X years our decision might be different, yet that decision not to engage might never be presented to us, because we would be in condition sufficiently to ameliorate our damages.

Representative DURHAM. On your theory, Mr. Kahn, then we would not have any war? Is that your idea? That things will get so terrible in the future that even Russia would not take a chance on attacking some other nation?

Mr. KAHN. There are two separate questions. One, involves such things as, for example, a Russian attack on West Germany. In this case they have not started world war III. They have just started a small war. At that point it is up to us to decide whether to start world war III, not the Russians. I am just giving you a hypothetical example. In other words, we must not confuse the horror of world war III with that which is risked when the Soviets try a moderately violent action. That is a quite different thing.

Second, the situation may not be symmetrical. It is conceivable that there are circumstances in which the Russians could strike the United States and accept our retaliatory blow, when we would not be willing to strike them and accept their retaliatory blow. This has to do partly with the intrinsic vulnerabilities of the two countries. As you know, we are a much more concentrated country than the Russians. But mainly it has to do with their attitude toward war and the seriousness with which they pursue preparations. The Russians, for example, have a very large civil defense program. It happens, as far as we can tell, to have some inadequacies. The intellectual basis of the program is very bad. It was not until 1954 that Soviet civil defense authorities discussed 20 KT bombs, it was not until the last year or two that they dropped the 20 KT bomb for the 20 MT bomb. We have been 3 or 4 years behind the problem. They have been 7 or 8. But if you look at Russian manuals, you will notice an enormous increase in understanding, ability, and capability in the last few years. I do not wish at this time to get into Russian programs. Mr. Holifield's other committee in the House has put out a report on Russian civil defense which has most of the information in it. What I am saying is that the Russians in 1954 and 1955 had a great debate on the theory of the "minimum deterrent." Malenkov said, the next war would mean the annihilation of civilization, "And therefore we lucky Russians don't have to have such a large force as we used to have, because if it really is annihilation, nobody will start a war, and we can afford to get away with a much cheaper strategic force. We can start concentrating on consumer goods."

He was forced to retract publicly on that argument. Khrushchev argued that wars weren't that bad and that the Soviets had to be prepared to fight and win wars in addition to being able to deter them. This was one of the major debates that they seem to have had and Khrushchev seems to be the official winner. As a result the Soviets have gone for a capability to win wars rather than to deter wars.

This is a deliberate choice on their part which involves them in great expense.

Whether they have carried through completely on that decision is not known in this country, in other words, one often makes a decision and then does not carry through. There is some evidence to the contrary, evidence that they have expanded the civilian sector of their economy at the expense of the military economy. But insofar as we can tell, they did make a decision in 1955 and 1956 to buy a capability to fight and win wars and have done some of the things they need to do to implement that decision.

We are making the exactly opposite decision. We are making a decision to deter wars. Failing deterrence, we do not talk seriously about the consequences.

And as I said earlier in the day, we do not analyze carefully what we mean by deterrence, because we have staked too much on the notion working to be able to analyze it objectively. There is too much that we are risking to be able to discuss the subject calmly, quietly, and objectively. Many of us feel we cannot afford to weaken our resolve by even thinking about possible weaknesses.

I think, though, that it is important that we do think this problem through, and this is why I was delighted at these hearings being held.

Representative DURHAM. You have to think pretty seriously to spend $70 billion of the taxpayers' money which goes directly into the defense and security of the free people of the world.

Mr. KAHN. Let me give you an example of what I mean. There is a great deal of criticism of the Federal Government today, to the effect that they are not spending enough money on defense. Nevertheless, there was a recent decision to cut back on air defense. As far as I know, that decision was not criticized publicly by anybody. The only criticism which was made of that decision was that the cutback on defense against bombers did not go far enough. Yet some years ago, in 1956, when General Partridge testified on the state of our defenses, he made it very clear they were not adequate to defend our country and would not be adequate in the near future; his testimony did not depend in any sharp way on large estimates of the numbers of Russian long-range bombers; their TU–4's, and Badgers, and small numbers of Bears and Bisons, being sufficient. They did not have to have 500 or 1,000 Bears and Bisons to do the job.

The reason why there is no criticism of the decision to cut back on air defense is that people believe we must deter allout war, we must be able to fight limited wars, we must have arms control and that is all. They do not really believe we have to be able to fight a general war, usually not because they are certain one cannot happen, but because they do not believe that anyone can survive a general war. They do not believe that there is a significant difference between victory, stalemate, and defeat.

The testimony before this committee was I think in that sense very salutary. As far as I know, Frank Shelton was the first Government official to make the flat statement that the next war would not destroy all human beings, worldwide.

This may strike those who know, in this committee room, as a rather silly view, held by maybe a few uneducated laymen. It is not like that. Very distinguished scientists hold that view. And I mean very

distinguished. And a couple of years ago they would have been willing to argue with you numerically that they were right. In fact, in the 1957 fallout hearings before this same committee, when questions were asked of the various scientists—unfortunately I do not have the exact quotations with me—but such questions as "What would happen if the Soviets dropped 100 5-megaton bombs on the United States?", the answer was generally to the effect, "I haven't made that calculation, but we couldn't take it." There was a recent debate in the New Leader magazine between Bertrand Russell and Sidney Hook on "Was it legitimate, or was it not, to risk killing all human beings in the world in the attempt to resist communism?" That was a serious debate. Nobody raised the question, that the debate was about a hypothetical subject which was not at issue. One does not kill all human beings, or even a majority of them, in a war. Today, in England, in France, serious experts on war almost always discuss the issue of war or peace in terms of world annihilation; never in terms of "the damage is great." In terms of, "Is the damage too large to accept, or will we prefer accepting that damage rather than appeasing or surrendering?" That is never the question. The question is always debated in terms of world annihilation or no world annihilation. This in spite of the fact that there is no scientific backing for that view for any practical kinds of wars that may occur in the near future.

Senator ANDERSON. When you say there was no objection to the cut back in the Air Force, are you really sure about that? Did not Senator Symington have quite a bit to say about it, and did not others in the Senate?

Mr. KAHN. I believe they had a lot to say, but always in the direction of wanting to cut back on air defense more. I would like to check it, but I believe that is correct. The statement was, "You people are still in the horse and buggy era. You are fighting ICBM's with chariots." The argument was always that we should shift more to defense against missiles, shift more to our deterrent force, shift more to limited war forces. As far as I know, and I am reasonably well read, though I did not expect this subject to be brought out today, so I did not check on it, there was no public voice raised in any of the standard large newspapers—I was curious, so I looked at all the editorials I could find—or any statement issued by any Member of Congress, that the cutback in active air defense was too much. The argument was all on the other side, that the cutback was not enough, in the defense against manned bombers. I am almost certain I would remember if I am wrong.

Representative HOLIFIELD. You confine that to the defense against manned bombers?

Mr. KAHN. Defense against manned bombers, that is, Nike, Bomarc, interceptors. I am not here making any comments as to Nike versus Bomarc or anythink like that. I am simply discussing the conceptual idea that people think the notion of defending against manned bombers is obsolete. This is a view that is widely spread, widely held in many places. Most people hold this notion as much because they think defense is obsolete as because they think bombers are obsolete.

I hope later to get into the philosophy of the deterrent forces, and this is very much connected with this notion.

I should make one other small point before I go into the systematic discussion, even though we are running out of time. And this is the question of the symmetrical character of what I call Type 1 Deterrence. In order to make it easier to remember, let me use the same terminology the British used. The British refer to the type 1 deterrent as a Passive Deterrent, because they argue it takes no act of will. In other words, if he strikes you, you will strike back. It does not take any courage or any will. They refer to Type 2 Deterrence as an active deterrence, because it takes an act of will. You have got to be willing to strike the enemy when he provokes you by striking a third party. It is not automatic.

Let us now consider Russian Active Deterrence for a moment, and ask ourselves: Is it easy to deter the Russians? Can we afford to provoke them as far as we wish to go?

Let me give an example. In 1956, there was a revolution in Hungary which the Russians suppressed. There was at that time much pressure on the United States to intervene in that revolution to support the Hungarians. I myself felt rather strongly we should do something. However, I wish to ask the following question: If we had intervened, would the Russians have accepted that intervention, say in 1956? Would they accept it in 1960? These are different situations. It is possible that we did more than not intervene. There are rumors—I do not know if they are true or not—that we broadcast to the East Germans and the Poles not to rock the boat, that American aid was not on the way if they did. There are reasons for worrying about a satellite revolt spreading and, if we had intervened, it is quite clear that there would very likely have been a widespread satellite revolt. Particularly if the Russians did nothing, if they just let us get away with it. After all, some of the satellites revolted without any American intervention.

A satellite revolt is a very big thing to the Russians, and they might not be willing to stand for it. Much more important, the Russians are greatly concerned with internal stability. Most Russian experts that I know of think of the Russians as having a very stable government, unlikely to be upset even by really quite catastrophic events. But it also seems to be true that the Russians do not think of themselves as quite that stable. They worry about internal revolution in Russia more than we do. And they might think of a successful satellite revolt as an intolerable event that might lead to the end of the regime.

They would, I think, be under pressure to fight if we intervened in Hungary. If the fight was on a high explosive basis, I think we would lose. If the fight was on an atomic basis, I think we would probably still lose, but now there would also be side effects. If the fighting were limited to Hungary, there would probably be widespread destruction within Hungary because neither of us would wish to lose without making a major effort. If we tried to limit the damage by attacking supply lines in rear areas we would be getting into Russian territory. Now, the Russians might think at this point that at any moment the war could erupt either into a satellite revolt or into a large scale attack on Russia. They might be particularly will-

ing to worry about the latter because they would find it very hard to believe that we intervened with the expectation of losing. In any case, it is a very large war being fought near Russia. They might then ask themselves the following question: Rather than wait for this war to erupt into a satellite revolt or into an American surprise attack on our strategic force, maybe it is safer for us to hit the United States and thus at least assure our getting that all important first strike—at least if we hurry.

In other words, they might argue that going to war is very risky, but possible less risky than not going to war. At this point we must ask the question: How risky is it for the Russians to go to war?

Well, in late 1956, it was very risky for them. We had a very large strategic force and one which was very alert. Even if they attacked the United States and caused much larger levels of damage than that discussed here, our strategic force would have flown away before they could have damaged it. ASSUMING BOMBERS, NOT FAST MISSILES!!

This situation may not, however, be as true in the future, for a number of reasons.

I would like to make this one observation at this point. If the Russians can limit our attack on them to about the size of this attack on the United States, then if they have made very modest preparations, they do not suffer a great deal of damage.

What do I mean by this? I mean that if they can evacuate their civilians to places of safety, radiological safety; then we can't kill very many Russians. There are lots of places to evacuate to in the Soviet Union. Let me give some orienting numbers. There are less than 50 million people in the largest 135 Russian cities. As far as we can tell it is perfectly possible to evacute 80 percent of this urban population and have all vital functions in the cities performed. This would leave only 10 million people at risk in 135 cities. Having been alerted, these could evacuate on very short notice. In addition it is very difficult to destroy 135 Soviet cities in a retaliatory blow. I am not saying we could not have done it. I think we could have, in 1956. But it is a difficult thing to do. You can see it is difficult. In any case it is a larger attack than this one.

Even if it did not kill many people such an attack would cause a lot of economic damage in Russia. But the Russians claim to have lost one-third of their wealth in World War II, and they recovered from it. In fact they recovered by 1951. And they know they recovered from such levels of damage, because they mention it. In other words, the Russians know that it can pay to accept very large amounts of damage, rather than to surrender, because they have actually gone through the experience. And while that is a very hard way to learn, it is also a very convincing way to learn by having actual experience. This doesn't mean they would be glad to repeat the experience—only that they may be willing to under less pressure than we would be willing to.

I mention both of these cases, because I want to put the rest of my discussion in context.

One not only has to ask himself what it costs us to go to war under certain circumstances, how do we feel about it, how do the Russians feel about it, how do the Europeans feel about it, but also the same set of questions about the other possibility—about Soviet willingness

to go to war. All of these questions must be asked. As I said, it does no good to convince the Russians and the Americans if you do not convince the Europeans simulaneously. Otherwise, we may get into real problems.

Representative DURHAM. Mr. Kahn, do you think that has anything to do with a man's will to fight for what he believes in?

Mr. KAHN. I believe it is very possible for a soldier to die for a squad, a squad for a regiment, a regiment for a division, a division for an army, an army for a nation. I doubt that under most circumstances it is possible for a Nation such as the United States to die for the world. It may be all right to fight to the last man, but most civilized nations will surrender or at least negotiate before fighting to the last woman and child.

Representative DURHAM. I am talking about the fact, of course, of the recovery in Russia. And of course they know what it will cost them.

Mr. KAHN. What I am saying is that I think both the United States and Russia will fight if sufficiently challenged, so long as there is at least a moderately good chance of their nation surviving the war; that if there is no chance at all of the nation surviving the war, they will not fight if only challenged. They will then only fight when they are in fact hit, rather than challenged. This remark is only reinforced if you believe the stakes are world annihilation.

What it amounts to is that you have to believe in life on other planets, in order to fight. And the evidence for that is scarce.

Now, actually, discussing this problem just in terms of casualties is very misleading, because if you ask: Why is it that most of the experts do not believe in recovery? It is not because they are worried about the large number of immediate deaths. It is because they are worried about the medical, economic and social problems of the postwar period and the long-range genetic problems. I have listed here the eight phases of a war one has to look at if one is trying to analyze. I would like to discuss these backwards, because that is the order of importance. (The list is in the outline of lecture I in the prepared statement, p. 921.)

Let me therefore start with the genetic effects as discussed at this hearing and as studied by our own people.

The first thing one has to decide is: What are the standards by which one is to measure if the situation is tolerable or intolerable? Now, there are three kinds of standards one should look at. First there are the prewar standards, the standards by which we regulate our public health today. There are the standards to be used during the war and immediate postwar situation. What will you accept when things are actually happening? You will for example accept 5 million casualties going without treatment and thereby dying, because there is no alterative; there is no way to treat them. You will simply add these casualties to the total of the fatalities. Then there are the postwar standards. Now, this war is a horrible thing, and its horror lasts for some thousands, actually tens of thousands, of years. The environment is permanently more hostile after such a war, in the sense that anything over 1,000 years is permanent, as far as we are concerned. And it actually turns out that if you believe that in the postwar world you will not live in an area which is unsafe to live in by

current peacetime standards, then you would abandon much of the country for decades. You will walk away from it. As you might guess, it probably won't be like that. We will both put in alleviating measures and adjust our standards. And the question that one has to ask oneself is not, "Will we abandon the country?" since there is no place to go, really, but how bad is it for us to use these alleviating measures and to readjust to reasonable postwar standards? Can I as an individual on the average hope to live a happy life? Can my descendants? Can society function in a way which we like to think of western societies functioning? Or will we live as the savages live, as some of the Asiatic nations live, with life expectancies of 25 years? When one asks the question this way, one may find situations "acceptable" in which the overall damage is really fantastically high.

Let me now make a comment or two about the genetic damage. We had testimony earlier that there might be a billion individuals injured if the survival was only 40 million. It was estimated that between 1 and 4 percent of this toll is represented by live, seriously defective individuals. No man can deny that this particular legacy of a war represents human tragedies in the most extreme form. However, the rest of the defects, representing 96–99 percent of the total, have a much smaller impact. Something like a half to three-quarters were so-called prenatal death, or early miscarriages, or things of that sort.

Now, while that may be an individual tragedy, it is not a social tragedy. In other words, Americans have so much excess fecundity that even if there are many early miscarriages, it does not affect society, though the individuals affected may be seriously perturbed.

It should be pointed out that many of these early miscarriages are not even noticed by the woman who is involved, because they occur very early.

The rest of these genetic defects were described as minor defects which might affect the health, happiness, and vigor of the individual but which generally do not show up in a dramatic way. It is very hard to estimate the impact of such minor defects. In particular, I think that here the geneticists tend to be somewhat misleading in their estimates of the impact, because they do not think or talk like economists. For example, there is a theorem in genetics which says something like the following: That almost any defective mutation is just as bad as any other mutation, because almost every defective mutation eventually causes a death.

In fact, sometimes a geneticist says that insofar as two mutations do not cause exactly the same damage, the one that results in a minor defect may cause more damage. The reasoning goes as follows: The minor defect is carried along generation after generation, affecting the health and happiness of each of its bearers adversely, until finally it tips the scale against an individual, causing him to die, terminating that genetic line. So both the minor and the major mutation killed an individual, but the minor not only killed an individual but affected the health and happiness of many other individuals in the process. And one can therefore argue that the minor mutation caused more damage.

The theorem is misleading, yet it affects a great deal of thinking among geneticists. It is misleading because, among other things, it

ignores a fact that any economist is familiar with, that one has to discount the future.

Let me give an example why this is proper if we are to use the words harm, damage, et cetera, properly. If I were asked to choose between three situations—a situation in which 100 percent of the people were killed immediately, or a situation in which 10 percent of each generation died prematurely, for 10 generations, or finally a situation in which 1 percent of each generation died prematurely for 100 generations—then the total number of individuals killed is exactly the same. But I think there is no question which situation most people would prefer.

In other words, if you can spread the damage over tens of thousands of years, you have done something very useful, and if the spread occurs naturally one must take account of the distribution of damage over time when one asks: How does it affect society or the average member of a society? One cannot just add up arithmetically over tens of thousands of years, the total amount of damage if one wishes to answer this question. From some moral points of view, the simple arithmetic sum may be the right way to think, but I have doubts even about that. It is true that "a human being is a human being." But, moral questions aside, from the viewpoint of how we as individuals view our personal expectations of happiness or our society's ability to function, the simple arithmetic sum is almost irrelevant.

I am not, in other words, discussing the moral question: Is it worse to kill a man 10,000 years from now or to kill him today?—not because I am not interested in that question, but because it is irrelevant to what I am discussing right now. That kind of question typically will not affect calculations of deterrence. It just does not.

I would like to tell a story to illustrate how strongly people feel about genetic damage, sometimes unreasonably strongly. At one point, I was induced, against my will—and I was sorry both before and afterward—to give a talk at UCLA to a mixed audience, on what a war might be like. I mentioned that in a typical war if one had taken modest preparations the survivors might get about 250 roentgens, that this dose might mean that for the next generation and some generations to follow 1 percent of the children would be born with serious defects, who would not otherwise have been defective, such defects as idiocy, blindness, crippling, and so on.

Then I added, injudiciously, that "One might be willing to accept that cost of a war, rather than give up Europe to the Soviets," or that under certain circumstances the Russians might be willing to accept that cost of a war in order to eliminate us. A woman got up in the audience and said, "I don't want to live in your world where 1 percent of the children are born defective." She then made some other rather pointed remarks.

I was outraged and answered, "It isn't my world." I have nothing special to do with it, I have to accept the same responsibility as everybody else in this room, but no more. I then pointed to my chart, which said: "About 4 percent of the children are currently born defective." Then a friend of mine offered the lady a knife. He was pretty mad, too.

The point of this story is that peace also has its tragedies. I can easily imagine that if we had lived in a world in which no children were born defective and we were told that as a result of some action of the Government or of a war that 4 percent of the children would be born seriously defective we would consider such a world to be intolerable. We just wouldn't be able to believe that people would be willing to bear and raise children if the risk were about 1 in 25 of these children having a serious congenital defect. However, we live in that world now and we not only bear this relatively high rate of tragedy, we almost ignore it. While some women have a great concern about such possibilities during their pregnancy it is only in such critical periods or when there is a tragedy in the immediate family that most people think about this burden of life. To add an additional 1 percent to the burden would be a terrible thing to do, but it is clear that this additional burden is comparable to the kinds of risks with which we have become accustomed to in the peacetime world, and that most people will be able to live with such increased risks.

In other words, war is horrible. There is no qustion about it. But so is peace. To some extent the horrors of war are only an increase or intensification of some of the familiar horrors of peace and if you present a government with a sufficiently unpleasant peacetime situation it may decide that it prefers to go to war and accept the postwar world to living or temporizing with the peacetime problem.

This is one reason why it is useful to make the kinds of calculations we are making today, to compare the horror of war and the horror of peace and see how much worse war is. This is an emotion-laden issue, partly because it gets mixed up with the question of nuclear testing where many people have overdone such comparisons or said, rather violently, that they are totally irrelevant.

It is perfectly possible, by the way, to feel that the nuclear tests cause too much damage but that the war does not, in the sense that the tests should be judged by peacetime standards and the war by wartime standards. These are not logically inconsistent views to have.

In any case, as nearly as I can see, if you have a reasonable economic recuperation, the genetic effects resulting from one war cannot jeopardize overall standards of living. It is difficult, if not impossible, to give people much more than a thousand roentgens in a war without killing them. Only the survivors have children. If current beliefs are true, 1,000 roentgens should at most double the normal burden of defects, probably less.

Now, doubling the number of burdens of defects is an enormous thing to do, but it should be almost clear that the medical and social cost to society of the current burden is not so high that we could not accept a double burden without jeopardizing the functioning of either our system or the Russian system. The individuals who are directly affected, of course, would feel involved in a tragedy. The rest of us would get along.

I would like now to look at the long-term medical effects of the war, again in the same context. Can we depend upon such effects as providing an automatic and reliable deterrent? As always, I want to ask the question both ways.

One problem which has raised much concern is the strontium 90 problem. It is possible to make a technically respectable calculation

which states that every time the Russians test a large bomb in the Soviet Arctic or we test one in the Pacific something like 1,000 to 10,000 individuals now alive will get bone cancer or leukemia as a result of that test. Nobody really knows, but you could put out such a calculation and not be read out of the profession. You can print it in a professional journal. It is a respectable calculation.

I think it is rather high, myself, but I would not care to challenge it as being obviously wrong. LINEAR, NO-THRESHOLD THEORY.

Many people have argued, both in the technical literature and in the literature of war, that if so few bombs so far away cause so much damage, would not a lot of bombs, very close, be annihilating?

Many "experts" have written that the backlash effect of fallout is itself a sufficient deterrent; in other words, that if the Russians drop a lot of bombs on the United States, they would be wiped out by the worldwide fallout. The simplest kind of arithmetic indicates this is not correct. In this attack you drop 4,000 megatons, which produces, say, about 250 times as much worldwide fallout as testing a large bomb produces. If one takes the largest number, 10,000 leukemias and bone cancers as resulting from testing a large bomb, and multiplies that by 250, one gets 2,500,000 individuals affected by worldwide fallout. The Russians have less than 10 percent of the population of the world, so if they received their prorata share of the backlash they would have to suffer 250,000 premature deaths over the next 30 or 40 years. That would not deter them from any action they badly wanted to take.

Furthermore, as I said, these numbers are probably overestimates. The backlash is not even an unreliable deterrent.

In fact, we have had a lot of testimony in this last 4 days, to the other effect, testimony which is new in the sense that it is rare for anybody to publicly take a sober view of this unpleasant subject.

Representative DURHAM. Mr. Kahn, do you think that kind of reasoning has anything to do with the fact that of course they will not agree to any kind of a testing ban at Geneva, which has been going on since last October?

Mr. KAHN. No, I think the test ban has the problem that the Russians do not want a system which could be used to give us intelligence and we do not want a system which is so loose the Russians could cheat, and those two desires meet head on. I think we are both willing to have bans if we can compromise these other desires.

Representative DURHAM. You know, of course, that they are putting strontium 90 into the air every time they run those tests.

Mr. KAHN. There are many reasons for stopping tests.

Representative DURHAM. I was just basing it on what you assume they could take.

Mr. KAHN. The biological effects of testing are not an overwhelming reason, as governmental decisions go, for stopping tests. The tests very likely do a lot of damage. But almost anything you do in society causes damage. If you were willing to stop tests for this reason alone, you would stop a lot of other things.

For example, there used to be a rule that every time you built a million dollars worth of construction you killed somebody.

Representative DURHAM. I assume you are saying that we can take the 2.5 million casualties and continue the testing, put the strontium in the air, and take those results.

Mr. KAHN. I am not predicting 2.5 million casualties as a result of testing.

Representative DURHAM. If you keep on testing, we will have as much in the air as we have in a war.

Mr. KAHN. With vigorous test programs you could get quite a bit.

Representative DURHAM. Do you want to put it out all at one time, or in the next 50 years, in other words?

Mr. KAHN. I believe if the issue came to having a defense or not having a defense, both sides would be willing to continue testing and accept the biological damage. I do not think that is necessarily the right issue, but if that were the issue, both sides would continue testing.

Mr. Chairman, I did get a little elaborate in my introduction. I am not sure how much more time I should take.

Representative HOLIFIELD. What is the pleasure of the committee?

Senator ANDERSON. He is doing fine.

Go ahead.

Mr. KAHN. Let us look at the strontium 90 in a bit more detail.

Representative HOLIFIELD. Speak a little slower, please, and a little plainer.

Mr. KAHN. It is believed today that about 10 millicuries of strontium 90 per square mile would result in people living in that environment having about one sunshine unit in their body. If there is no fractionation, this corresponds roughly to one ten-thousandth of a KT of fission products per square mile. Since we allow people to have no more than 100 sunshine units in their body, this would imply that the soil is unusable if it is contaminated by as little as one one-hundredth of a KT per square mile.

Some of you may have seen statements recently that after a large thermonuclear war there would be no agriculture in the United States for 40 years; the soil would be so badly contaminated one could not eat the food. This has come up several times in questioning by various congressional committees. If you feel, as our peacetime standards indicate you should feel, that you would not eat food grown in soil contaminated by one one-hundredth of a KT of fission products, then it is very easy to contaminate the whole United States. You grow food in about a million square miles in the United States so it takes only 10 megatons of fission products to contaminate the United States to the point where you would not be willing to eat food grown on that soil.

Senator ANDERSON. How many?

Mr. KAHN. About 10 megatons of fission products spread uniformly over a million square miles of the United States. It would contaminate the United States to the point where one would not today accept food grown on that soil as fit for human consumption.

If we increase the contamination by a factor of 10, to take account of decay and weathering over the next 50 years, and by another factor of 10 to take account of overlap, one gets that about 1,000 megatons are needed to contaminate U.S. agricultural lands.

Representative HOLIFIELD. Of course, you are considering a mathematical even spread. You are not saying a 10-megaton bomb would do this.

Mr. KAHN. No. But I am saying that it is 10 megatons if uniformly spread. Multiply by 10 to take account of decay and weathering. Multiply by another 10 to take care of nonuniformities.

Now, the calculation is misleading. But it is persuasive. And you have to know why it is misleading. Otherwise, you will be persuaded.

It is wrong for many reasons, one of the most important being that the peacetime standards are probably not legitimate for the postwar world. It is also wrong because it does not take account of the fact that we will do many things to alleviate the problem.

I am not a medical doctor, and it would not be appropriate for me to suggest possible postwar standards. But just for the purpose of discussion, let me do exactly that, to give a feeling for some of the considerations which might come up.

I suggest that we would be willing to accept something like 50 to 100 sunshine units in our children, in the postwar world, not because we are happy about the idea but because it is a little difficult to achieve much less than that unless we make some preparations.

Representative HOLIFIELD. We have been using the term "strontium unit" rather than "sunshine." Some of us are allergic to this term "sunshine." We prefer the term "strontium."

Mr. KAHN. I could not agree with you more. Strontium 90 is manufactured by men. Sunshine is not. Let us keep it to a manmade object.

Senator ANDERSON. I think that term sunshine came because the first time they said if the fallout came down very, very slowly, that was good for you. And then later they said if it came down very fast, that was good for you. We decided to take the sunshine, in view of everything.

Mr. KAHN. I prefer not getting into that debate. I deal in a number of controversial subjects, but I try to keep the number down.

To continue, one might be willing to accept 50 or maybe a hundred, even, strontium units in our children, if we had to. Let us call food that would result in this or lower levels an A food. The A food would be restricted to children and pregnant mothers. One might then also have a B food which might be about 10 times as contaminated as the A food. This would be a high-priced food, available to everybody. There might then be another grade of food, a C food, which would have another factor of 10 more contamination. This would be a cheap food available to all. We are now talking about having up to 10 microcuries in new bone, which is quite a bit.

But I might point out, no one has ever seeen a bone cancer directly attributable to radioactive material in the bone at less than the equivalent of 20 to 30 microcuries. Now, we are reasonably sure that smaller amounts will cause bone cancers in a statistical sense; but I would guess that at least an adult insurance company would not raise its premium very much if one lived on food with that amount of strontium 90 in it. Ten microcuries of Sr^{90} per kg. of calcium would mean a dose of about 20 roentgens a year in the bones. This would probably cause less than a year's loss of life expectancy. The C food is especially acceptable if it is mainly restricted to adults who would pick up much less Sr^{90} than children would.

Then I would suggest another factor of 10 for a D-food, which is not available to the general public but is restricted to people over 40, or maybe over 50. It is difficult to kill a man over 40 or 50 with Sr^{90}. People of this age group do not absorb very much, and it takes 20 or 30 years to get bone cancer. One dies of something else before he does of bone cancer.

One reason why I am suggesting setting up tentative standards now is that we really have to have, before the war, some notion of what we are willing to live with, to guide research, to guide planning, and to eliminate hysteria in a crisis.

There is another reason why it is important to set up in peace the war and postwar standards we think we may have to adopt. In addition to determining these standards, the Government should formally publish them in a permanent looking form that will be available for at least postattack or postcrisis distribution. It is not really necessary to distribute all of the handbooks prewar as people can usually read them either during or after the crisis or attack, though they should be made available to all who are interested. It is, however, important to print them ahead of time, not only so that they will be immediately available, but also so that people will trust the information in them. In any such crisis many will be cynical of the integrity of the Government and will argue that the Government says these standards are acceptable because it must say so, that conditions are such that it has no choice, but that in fact the standards will result in a drastic level of casualties. The knowledge that the standards were set up in peacetime after due care and debate should be reassuring.

I am not suggesting we should publicize the existence and character of the postwar standards. I am not suggesting we should tell everybody they will get bone cancer. I am merely suggesting that the manuals be printed, stockpiled, and a small circulation made to those who are interested.

I had a discussion with a rather senior official in the AEC suggesting this. He looked at me rather amazed. They aren't very happy at the thought of putting out anything that could be construed as suggesting they are underestimating the Sr^{90} problem.

Incidentally, this official asked me, "What do you think the difference in price would be between the B and C foods?"

I said, "About 5 or 10 cents a quart."

He said, "You could not sell one for less than $50 a quart difference."

If it is in fact true that people would not be willing to eat foods contaminated with a microcurie or so of strontium 90 per kilogram of calcium, then I think we are not going to recover very expeditiously from this war.

It is only because, for a short time, we are willing to eat such food, that I believe our recovery would be rapid. If this is not true, then we are either not going to have food, or we will put much energy into obtaining food that should go into other reconstruction projects.

It is important to realize that world agriculture would soon adjust to this problem. We would find the United States growing nonfood crops and meat and Argentina growing dairy products, and so on. In a relatively short period of time, if there is recovery, the patterns of agriculture will adjust to the contamination, and while food may cost a little bit more, it will not be excessive in either price or contamination.

Therefore, in all likelihood, the Sr^{90} problem is a short-term problem, but it still must be treated objectively and soberly, without any unnecessary panic or hysteria for that first 3, 4, or 5 years. I should also mention that there are other alleviating measures that will help.

I would like to repeat, it is really important that we treat this and other problems ahead of time, because if we do not, and wait until the crisis, we are going to find somebody raising this question, and we will not be able to answer it convincingly on that day. We must have thought this thing through long before the Russians ask us to think it through. Among other reasons, because it has to be debated.

Representative HOLIFIELD. What you are advocating is to take these problems that are imminent and put them on the table, talk them through, and get the most authoritative information on each one now, so people will know what they face?

Mr. KAHN. For this purpose I am not really so much interested in the people, though I have the same interest in them that you have. I am talking about the experts knowing what they face, the men who advise the Government during the crisis. You do not want them panicking. In fact, to be really frank, if there was any way of getting the initial discussion restricted to just 10,000 people, I would like to do it that way.

Representative HOLIFIELD. Why?

Mr. KAHN. I want to get as many technical arguments as possible out of the way before we fill the headlines with them. I prefer these technical arguments occurring not behind closed doors but in the technical arena. Unfortunately we cannot do it that way.

Representative HOLIFIELD. In other words, you believe the scientists should come forward with the scientific information and settle the fights among themselves before submittnig the conclusions to lay people, who are not technically qualified to form judgments. Is that your position?

Mr. KAHN. I don't think that is completely possible in our form of society or even desirable, so I am not recommending it. But if it could be done a little bit like that, I would prefer it.

You do get a lot of misinformation in the headlines, and people do get overly scared, or underly scared. They are entitled to this information, they should have it, but they are not entitled to misinformation or even unsophisticated notions.

Representative HOLIFIED. You are not denying the right of any individual to make any conclusion on the basis of a moral or a philosophical or a spiritual conviction?

Mr. KAHN. Absolutely not.

Representative HOLIFIELD. But what you are saying is that the information should be available for those people who wish to make the basic conclusion on the facts. Then let them apply them in any way they want to, morally, philosophically, or spiritually?

Mr. KAHN. Right. To give you an example of the difference, in the 1957 hearings on fallout, people were talking about things like a fraction of a roentgen. And yet they were using very cataclysmic language. In the current hearings, in reference to much higher amounts, witnesses are always adding words, to the effect, incredible as this is, the country can survive it.

Senator ANDERSON. Has the National Academy of Sciences done anything along this line?

Mr. KAHN. Yes, there is a great deal of information available today. And it is not the technical information that is in dispute, really. It is how you feel about it. What is your attitude toward it? People have not really evaluated this technical information in terms of reasonable postwar standards. This is not a technical decision in the sense of something one learns in school or even in a laboratory. These are things which Congressmen and the public must be involved in. But it is well to get the debate some distance among the experts before it is opened up. That is all I am saying.

Senator ANDERSON. But when the Federation of American Scientists want to talk about this, people say, "Oh, maybe some of them are left-wingers." That is the major difficulty, is it not?

Mr. KAHN. It is one of the major difficulties. I have a paper listing 52 Nobel laureates who signed a statement to the effect: "All nations must come to the decision to renounce force as a final result of policy. If they are not prepared to do this, they will cease to exist." If you look at that list of 52 of our most distinguished scientists, you cannot dismiss them as just a bunch of left-wing radicals making this extreme statement. Most of them are just scientists who have either made or think they have made, seen or think they have seen, calculations which imply just what they said. But the statement is extreme. It says, "All nations," and says, "cease to exist." It does not say "damage." Well, this is the kind of remark you get early in the discussion. It would be better if the statement could have been debated some before it was released.

Now, there is an important point here. I am not saying that a war that occurred in the year 2000, or even in 1975, might not be almost as cataclysmic as this. It is getting worse on a year-by-year basis, and many of my friends tell me, "Herman, you really shouldn't go around saying that people can fight and survive wars, because, after all, 10 or 20 years from now you may be obsolete, and it takes 10 or 20 years to explain things to people, so let's start now."

That is a judgment which I think (a) they have no right to make, and (b) is wrong. These problems of ours must be met on a year-to-year basis. We cannot get to 1975 if we do not get to 1960 and 1965.

Furthermore, no matter what your picture of a future utopia is, and we all have one, or you cannot live in this world, you have to get there, and getting there may be harder than drawing one up.

In other words, we have to be able to meet the challenge as they come on a year-by-year basis. This means we have to understand what the problem is on a year-by-year basis. Transition arrangements are just as important as final states.

Representative HOSMER. Are you not to some extent making an evaluation of what you would have in 1965, or be willing to accept in the way of a world in which to live; in one case if there was a nuclear war, and in the other case if you avoided it by accepting some other alternative, which might produce some comparable situations that were less acceptable than those created by the war?

Mr. KAHN. That is part of what I have been saying. But it is difficult to limit technological progress. Let me give you a feeling of what the future may hold. The public press has referred to bega-

ton bombs, for example. I am not saying such bombs are possible or not possible, but there is no law of physics which says they are not possible. You just cannot limit man's technology, and therefore it might literally be possible for human beings to blow the world into little pieces at some date within our expected lifetime, well within it, maybe. And it is clear that when that instant arrives, if you are going to fight a war at all, you have to fight it carefully, or maybe you cannot fight at all.

Unfortunately, war has had an important role in human institutions for many years now. The regulatory effect of the threat of force has also been important. It is a little hard to believe that all of our problems are going to be solved. It is hard to believe that just because you cannot strike the other person any more, that he will then behave very well.

I would like to emphasize: Britain declared war on Germany in 1914. Britain declared war on Germany in 1939. If they had not been able to declare war in either of those 2 years, they would have had to let the Germans do whatever they wanted to do.

However, it may well be, though, that we will face problems in the near future which are just not solvable by the techniques we have used in the past. In fact, that is true today to some extent. And it may well be that we should start on this new world right now. But it is a mistake to say that the new world has arrived today. It does not seem to be true.

I have a book with me today which I recommend to those who want to exaggerate the impact of thermonuclear war. It is called "Munich: Prologue to Tragedy," by Wheeler Bennet. Among other things Wheeler Bennet discusses why Chamberlain and Daladier folded. When they returned from Munich they were cheered by their people in Paris and London, because war had been averted. Over that weekend some people began to understand that war had been averted by a sellout of the worst sort. And on Monday some few were prepared to criticize. But if you read the debate, you noticed something very significant. The people who criticized Chamberlain and Daladier, with a couple of exceptions, did not criticize them for not going to war; they said, "Hitler was bluffing, and you should have stood your ground."

As far as we can tell, Hitler was not bluffing. The men who were in the room with him could see he was not bluffing. It was easy for the people back home to say he was bluffing, but not for the men who had the decision to make. The German people did not want war. The German Army did not want war. They literally threatened to have a military revolution. But Hitler seems to have been willing to have a war if he couldn't have his way.

We may be asked that same question. If the other man is not bluffing, and he may not be, then we have to ask ourselves, "Are we willing to fight or are we not? Do we have an alternative to peace?" It is just that simple.

Let me mention one more thing about the strontium 90 problem which gives one more reason why people are so concerned.

If you had tried to predict the effects of this kind of contamination before we had carried out these worldwide experiments, the testing in the Pacific and the Soviet Arctic, you would have probably estimated the concentration in new bone as about 10 times larger than it is.

It turns out that the chain which brings Sr^{90} into the human body from the fallout to the grass, to the cow, to the milk, to the intestines, to the bone, discriminates against strontium 90 versus calcium. This is purely fortuitous. Nobody would have predicted it ahead of time. If you had been rather subtle in your calculations, you might have realized this uncertainty existed and taken a factor of 10 against you. That would have made the predicted problem a hundred times worse than it is.

Now, certainly if the problem came up very suddenly in a crisis, and you wanted to make a conservative calculation, you would have taken the 10 against you, and would have predicted a problem 100 times worse than it is, and you would not be talking about A, B, and C foods, but about the abandonment of the country or at least of agriculture. We were just lucky, so to speak.

If you look at the other problems which bother people, the carbon 14 problem, for example, it is not so bad, but it has a similar characteristic. One of the problems that bothers people most about it is that 10,000 years after the war is over carbon 14 will still be causing genetic damage. That is a horrible thing to think of—you have a war today, and 10,000 years from now people are still suffering from the consequences of that war.

But from our point of view that damage, though acceptable over 10,000 years, is much less acceptable if it is taken in, say, 20 years. If carbon 14 had a lifetime of only 20 years, you would be much less willing to face the possibility of a war and more willing to appease. And if it was a really big war you could not face it, because you would be getting thousands of roentgens in one generation rather than 50. SPECIFIC ACTIVITY $\propto$ 1/(HALF LIFE)

The point I am trying to make is that you cannot say, as people are sometimes tempted to say, that man has faced plenty of things in the past and therefore can face this also, that man always has and therefore always will rise to the occasion. No man can rise to the occasion with a thousand millicuries of strontium 90 in his body or a dose of 3,000 roentgens.

The reason why I and my colleagues feel that the United States or Russia can survive this war is because we have experimental and theoretical data and have made calculations.

To put it in the words of the physicists, there is no conservation theorem which states one can get through this war. It takes data and calculations to show it.

That is a very frightening thing, because that means you are depending on theory. And, as you know, theories have gone astray. Even bridges occasionally fall down.

Now, if you look at the kinds of wars discussed in the last 4 days, there is such a large factor of safety present—and I think some of the testimony was pretty extreme, but most of it was very responsible—you can really feel that you can get through a war in the near future. Nobody today knows whether you could get through a war 30 years from now, even if you spent tens and hundreds of billions of dollars, because the problem may get much worse. We estimate that just to answer some of the relevant questions would cost $200 million. These are complicated questions.

Representative HOSMER. You did make some calculations, I believe; what it would take in time and resources to achieve a return to prewar standards.

Mr. KAHN. Let me do that in just one moment.

I am not trying to say one cannot face wars in the more distant future. I am just saying we do not know. We should find out.

If you look at an attack such as the one this committee looked at, you will find that more than half of the wealth of the country survives the attack. You find that much more than half of the population survives. You find you have a great many resources left over. Many people think of this as a very misleading observation. That is, they think of a human society as being similar to human bodies. If you destroy one vital organ, the body dies. The hair cells might linger on for a while, but eventually everything dies.

Now, that is not our view of society. It is rather interesting that before World War I, many experts had the same view of international trade. They argued that wars had to be short, because nations were so dependent on international trade that if it was cut off they would die. Today we know that this is not true and we use the same international analogy in our study.

We divide the country into two separate countries, an A country composed of, say, the largest 50 to 100 metropolitan areas. (A metropolitan area includes neighboring suburbs.) Then we say there is a B country, the rest of the country, the medium cities, small cities, towns, rural areas.

We notice that the B country has a large population, well over 100 million people, that it has a lot of wealth, that even if the A country was completely destroyed, the B country could probably not only survive that destruction but rebuild the A country in something like 10 years.

Now, we have no faith in that calculation. It is a calculation which nobody knows how to make. But we do not know whether the calculation is optimistic or pessimistic. It is just the best we can do.

My time seems to be running out, so let me finish by making some caveats. For this size of attack I do not know if these caveats are very important, though it would be important for a much larger attack.

We believe that if one dusted the United States with the fallout from this kind of attack and did no other damage than if we had made cheap preparations for attacks of the size studied by the committee and expensive preparations for much larger attacks, we could handle all the radioactivity problems. We believe that if you evacuated the A country and destroyed it totally, these 50 or 100 largest cities, and did nothing else, that we could rebuild these cities in 10 years or so.

We also believe that if you did nothing else but just kill one-third of the population of the United States, the other two-thirds would not commit suicide. They would bury their dead, go into a period of mourning, and then life would go on. It is just that simple.

But there is a very important question which we never even looked at. What if you do all of these things together and do many other things?

Certain data were presented yesterday on ecological effects, these large fires and things like that. I think that data is a little premature.

It probably does not correspond to a war of this sort, but a war maybe 5 or 10 years from now. But still you are doing things like that. You are burning large areas of the country. You are killing more insects than birds, and other things of that nature.

Now, it is our belief, not strongly held, but moderately strongly held, that for an attack this size, these interacting and unlooked at effects will probably not be crucial. For a larger attack, we are certain they are very important and have to be looked at insofar as they can be looked at.

Senator ANDERSON. I asked a very able scientist one time what he thought the outcome of a nuclear war would be. He said, "Well, if you would give me one of the caverns in your State where I can hide one plane and put one bomb in it, I would wait 3 days after the war started, and then I would try to find the one remaining person in the world and kill him with that bomb." He felt it would be total destruction.

You do not think it will be that way?

Mr. KAHN. It is not like that at all, so far as we can tell.

Senator ANDERSON. At Sarajevo there was one little rifle shot, but before we got through there was quite a little shooting.

Mr. KAHN. In the three lectures I try to discuss how wars terminate. This is a very complicated and uncertain subject. But, like anything else, one can conjecture and speculate. As near as I can tell, in most wars one side or the other gets a commanding lead very fast. In other words, you do not go down together. One side gets very much ahead. And then the only question that arises is a variation of the following. The side which is ahead can tell the side which is behind, "Unless you surrender or negotiate, I will physically destroy you. I will literally kill every point of resistance. I prefer you surrendering (a) because I am a humanitarian, (b) because you can hurt me while you are going down and I prefer that you don't hurt me any more than you have." The side which is behind has the choice of trying to use its remaining power of destruction to get a good bargain, but its bargaining position is weak.

Now, if you look at this bargaining in detail, you notice that there is a great pressure of time, communications, control problems. It is a very bizarre world; it is not like an international conference at Geneva. One cannot propose complicated diplomatic formulae. The demands must be very simple. Whether they will be accepted or whether the war will be fought to the bitter end is unpredictable. Once you get into this kind of thing, you can only conjecture what will happen. But one thing seems relatively likely, a war in which both sides go down together and fight it out to the last plane and so on is a very hard war to envisage, if you look at exercises, maps, and the effects of modern weapons. It just does not seem to be like that, for most wars. The only one in which it seems to be possible is one where the war starts accidentally, where no side made any real preparations.

But if one side gets in a very good first strike, it will in all probability, in a very real sense, win the war.

Senator ANDERSON. I am afraid that we are going to have to terminate here.

Representative HOSMER. Before we do go, I would like to call attention that on page 8 ways and means are spoken of to ameliorate a thermonuclear war. They will be in the printed hearings.

(The prepared statement of Herman Kahn follows:)

MAJOR IMPLICATIONS OF A STUDY OF NUCLEAR WAR[1]

Herman Kahn, Rand Corp.

The general belief persists today that an all-out thermonuclear war would inevitably result in mutual annihilation, and that nothing can be done to make it otherwise. Even those who do not believe in total annihilation often do believe that the shock effect of the casualties, the immediate destruction of wealth, and the long-term deleterious effects of fallout would inevitably jeopardize the survival of civilization.

A study recently carried out by the author and a number of his colleagues at Rand, and privately financed by the Rand Corp., has reached conclusions that seriously question these beliefs.[2] While a thermonuclear war would be a catastrophe—in some ways an unprecedented catastrophe—it would still be limited catastrophe. Even more important, the limits on the magnitude of the catastrophe might be sharply dependent on what prewar measures had been taken. The study suggests that for the next 10 or 15 years, and perhaps for much longer, feasible combinations of military and nonmilitary defense measures can come pretty close to preserving a reasonable semblance of our prewar society.

As long as we think of a thermonuclear war as a sort of end of history, we may not feel acutely uncomfortable about placing all of our reliance either on deterrence or on measures to alleviate tension, as this seems to be all we can do. We may also feel that if war automatically means mutual annihilation surely no one would start one. However, as soon as we realize that it is technically and economically possible to alleviate the consequences of a war, then some of these psychological blocks to consideration of additional actions should disappear. The measures suggested by this study are not substitutes for adequate deterrent forces nor for sensible attempts to alleviate tension. They are insurance against the possible failure of these first priority measures and a complement to them.

Our study was not a large effort. It was done by a team of about 20 professionals, drawn from various fields, who worked an average of four months on this problem. We tried to answer or define all the serious questions about nonmilitary defense. Obviously we could not examine these questions in great depth and detail; thus, the numbers the study produced might well change with further investigation. The results, however, are plausible and should be far better than most intuitive feelings and preconceptions about this critical subject.

DESCRIPTION OF THE POSSIBILITIES

Our analysis has brought forth the following results. While it is suggested that these be re-examined by a more complete study, we have sufficient confidence in them to suggest a $500 million program, described later. Roughly we decided that:

There are a number of combinations of military and nonmilitary measures which could provide valuable levels of protection in a nuclear war. The level of protection depends on the size of the program and the nature and magnitude of the attack. Inexpensive measures designed to insure national survival in an all-out war of the early 1960's might be fairly cheap and relatively reliable—something of the order of a billion dollars or a fraction thereof should be sufficient. More complete programs, designed to protect more than the most easily protected people, would be more expensive. Because such programs cost in the tens of billions of dollars, they are automatically controversial. However, we believe that at least the inexpensive programs should be carried out—so that if a war should occur the majority of our population would not only survive the war but would be able to restore some semblance of prewar society quite rapidly. In a war of the early 1970's, even minimum measures to insure survival might be expensive (in the tens of billions) and probably less reliable. (Cost and

---

[1] This paper is a revised version of an article, "How Many Can Be Saved," that appeared in the Bulletin of the Atomic Scientists, vol. XV, No. 1, January 1959.

[2] "Report on a Study of Nonmilitary Defense," the Rand Corp. Rept. R-322-RC, July 1, 1958.

performance change with time because the enemy threat changes.) However, at least a start should be made in preparing such measures.

Oversimplifying a bit, one can say that during this 1960–70 period against a premeditated all-out surprise attack, moderate nonmilitary defense programs, if combined with reasonable military programs, should protect about half the population with high confidence, an additional one-fourth with medium confidence, and a final one-fourth with low confidence. A phased program might start with relatively cheap measures for 1960, develop into a minimum fallout program and then possibly later into a quite adequate or "luxurious" program which included blast shelters. While the planning should be done on this basis, there need be no irrevocable commitments to go ahead with the next phase if for any reason it seemed desirable to slow the program down or stop it.

It should be noted that wars can start in a manner other than a premeditated program and then possibly later into a quite adequate or "luxurious" program might be very effective. Therefore, even if we are not willing to pay the cost for complete preparedness, we might be willing to initiate partial programs. These partial programs could be combined with prewar mobilization capabilities designed to put in an adequate program in a few years if the international situation deteriorates. It is plausible to consider such prewar mobilization capabilities because a country with a gross national product of about $500 billion and a construction industry whose capacity is close to $100 billion can contemplate doing things in a hurry if cheap but time-consuming preliminaries such as those involved in research, development, planning, analysis, design, programing, and legal hurdles have been eliminated.

In addition to protecting people from the immediate effects of the war, it is necessary to insure their survival in the postwar environment and then to restore prewar standards of living if possible. Our study also indicated that:

Shelters with long occupancy time and the use of known anti-contamination techniques should make it possible to handle the acute radiation problem (during the first 3 months) from even severe attacks.

With only moderate preparations in the early period and more elaborate ones in the later, it should be possible to handle short-term (3–24 months) survival, patchup, and repair problems.

Combinations of military and nonmilitary measures could protect enough capital to enable the economy to be restored to about half the prewar levels in the first year. The recuperation to prewar levels might be much faster (5–15 years) than has been generally supposed. In any case, if reasonable measures were taken the economy, on a per capita basis, would in all probability not drop below 1930–40 levels, except perhaps in the first postwar year.

Long-lived radioactivity problems, while serious, could be alleviated to the extent that, in comparison with the direct effects of the war, they would have a relatively minor impact on the economy or personal life of the population. Subject to uncertainties, the same should be true of the genetic effects. Even though these may last for a thousand years, the burden on any single generation should only be a fractional increase over the current normal burden of congenital defects.

IMPLICATIONS FOR DETERRENCE

U.S. national policy rests on a deterrent strategy. Presumably, deterrence of Soviet attack depends upon Soviet calculations of their risks versus their chances of success. Our study distinguishes three types of deterrence in examining the implications of nonmilitary defense:

Type I—Deterrence of a direct attack on the United States. In this case any calculation the Soviets might make would assume they have the first strike and the United States strikes back with a damaged force. (Calculations ignoring the effects of the first strike and therefore based on the preattack inventory of forces can be very misleading.) The Soviets then ask themselves what damage they are likely to suffer before hostilities end. Here the Soviet Union's estimate of the effectiveness of their passive defense preparations may play a crucial role, and the United States should examine these to see what questions they raise. Presumably since the Soviets can count on warning, and because they need only defend themselves against a damaged force, even moderate preparations might be considered effective under some circumstances. It is not that the Soviets could reliably expect to be untouched, but that a situation might arise in which the Soviets might feel that going to war was the least risky of the available alternatives.

U.S. nonmilitary defense programs will probably have only a marginal effect on U.S. type I deterrence. Because the war will almost undoubtedly be short and fought with existing stocks, civilian production and morale are unimportant to the military course of events. The chief importance of U.S. nonmilitary defense in this case resides in more or less accidental byproducts such as protected communications, survival of off-duty personnel, greater ability to improvise and augment SAC-type forces for second and later strikes, and possibly most important of all, a resistance to post-attack blackmail tactics which might otherwise succeede in at least partially disarming our surviving SAC forces.

. Type II—Deterrence of extremely provocative behavior. The Soviets now ask themselves if they can force the United States to accept peacefully the consequences of some extremely provocative action (say a large-scale attack on Europe or a Munich-type crisis). They presumably ask themselves, "What is the U.S. risk-gain calculation?"—crediting the United States with the first strike. Under these circumstances, in which there has been a tense situation, the Soviet Union strikes second with a damaged force; and when U.S. warning problems have been simplified, even modest civil defense programs relying mainly on evacuation and improvisation might perform impressively enough to make it clear to the Soviet planner and to our allies that there is a good possibility, if not a certainty, that the United States would not accept the provocation peacefully. If the Soviets were not deterred then the United States might actually carry out an evacuation to try to persuade them to desist. If the evacuation did not persuade the Soviets to desist, then in the last resort the United States might decide that it was less risky to go to war than to acquiesce.

The ability and willingness of the United States to engage in type II deterrence activities will be strongly affected by our type I deterrence capabilities. Because using type II deterrence automatically strains our type I deterrence (particularly if we try the evacuation maneuvers), we now need more of it. Almost all of the remarks made about type II deterrence carry over to our ability to wage and limit "limited wars."

Type II deterrence is, of course, symmetrical. There is an enormous difference in the bargaining ability of a country which can, for example, put its people in a place of safety on 24 hours' notice, and one which cannot. If it is hard for the reader to visualize this, let him imagine a situation where the Russians had prepared for exactly that and we had not. Then let him ask himself how he thinks we would come out at a subsequent Munich-type conference.

Type III—Deterrence of moderately provocative actions. In this case it would be wishful thinking to expect deterrence to work most of the time. However, Soviet calculations which contemplate provoking the United States might be influenced by the existence of a U.S. plan for a crash nonmilitary defense program. If a Soviet provocation touched off such a U.S. program, then the Soviets would probably be forced either to match this program, accept a position of inferiority, or possibly even strike immediately. In all cases, the costs and risks to them of their provocation are increased. If this possibility is made clear and probable, the Soviets should include these costs and risks in their calculations. Our type III deterrence is also affected by Soviet nonmilitary defense programs because their willingness to be aggressive and their bargaining ability may be influenced by the risks they run.

A converse effect may be an important additional bonus of even a modest start toward a realistic U.S. civil defense program. Such a program makes more "rational" a strong foreign policy (when a strong foreign policy might seem desirable) by decreasing the immediate risks. Making a stronger foreign policy more "rational" may or may not make it more probable, but at least it is made more credible. This should help in deterring some minor as well as extreme provocations. Even an explicit mobilization capability can be important because it should make it credible to our allies that we will at least be able to put ourselves soon into a position where we can rationally back them.

IMPACT ON MILITARY MISSIONS

The study made a superficial investigation of the components of nonmilitary defense and their relationship to complete and balanced defense and deterrence systems. For example, nonmilitary defense provides a new perspective for studies of active air defense and offense. Most air defense studies have tried to devise systems to protect the U.S. mobilization base—economic resources and population—with a high level of certainty. Actually, this goal can be made to seem attainable only if unrealistically optimistic assumptions are made. The

result is either a dangerous over-optimism about the power of defense or an equally dangerous apathy and despair. Similar remarks can be made about our strategic offense insofar as it is designed only to deter and not to fight a war. Such viewpoints tend to ignore the very important role our defense and offense systems can have between these two extremes in alleviating the consequences of war.

Because a nuclear war would be horrible, it takes an act of imagination to visualize one starting; but it should not take a further act of imagination to believe that such a war would end. As part of the study we considered various ways in which a war might terminate. If one or both sides were improperly prepared, such a war might end in a few hours by the almost total destruction of the military forces of one side by the other. If, however, both sides had made even moderate (but realistic) preparations to fight a long war—a war of at least a few days duration—then appreciably military forces should be left on both sides after the initial onslaught. And this in turn means that there are advantages to both sides in ending the war by negotiation.

Certain tactics facilitate a quick and favorable end by negotiation. For example, one side can avoid some large fraction of the other side's cities and use the threat of destruction of these cities both as a hostage for the enemy's good behavior and as an inducement to negotiate. Similarly, the other side can adopt a similar tactic and use the threat of his surviving forces to compel the enemy to offer "reasonable" terms. As in classical warfare, the "reserves" may play a central role.

No matter what sequence of events is imagined, the possibility that the offense and defense could survive for some days is important. Nevertheless, most discussions of new strategic systems appear overly concerned with wars that last less than 1 day. If we are seriously interested in alleviating the consequences of a war, then we are interested in having military capabilities—both offensive and defensive—on the second and third days of the war. In fact, sensible military planning would provide for wars lasting from 2 to 30 days, though the first day—or even hours—of the war is still likely to be of the utmost significance.

INTERACTIONS WITH DISARMAMENT

The most obvious effect of civil defense on disarmament is the reduction in the vulnerability of the civilian targets. This has only an indirect effect on the military situation of a potential defender since most civilians and their buildings are not really military targets. However, a reduction in civilian vulnerability may be of major importance in reducing the risk that a potential aggressor faces. Presumably he can contemplate accepting a larger retaliatory strike if he has a reasonable nonmilitary defense program than he could if he didn't have one. To this extent a civil defense program conflicts with some of the objectives of a disarmament program.

There are, however, two very important ways in which civil defense programs may help a disarmament program. First, the civil defense programs make a nation somewhat less vulnerable to blackmail or a breakdown of the disarmament agreement. If a nation is totally vulnerable to an attack, then it is also totally vulnerable to blackmail and the fact that it might be able to destroy the blackmailing nation does not necessarily help. It is just not credible that a nation such as the United States will consciously and deliberately choose suicide while there is any hope of life. In other words, pure disarmament programs without any civil defense make no allowance for type II or type III deterrence. It is extremely wishful thinking to believe that such things will never be necessary. It may be positively dangerous deliberately to weaken our type II or type III deterrence to the point where it is an invitation to a potential aggressor. Furthermore, even a disarmament program will not completely exclude the possibility of accidental or unpremeditated war. Finally, even the best disarmament agreement might be repudiated or violated—possibly initiating a sequence of events which lead to war. It is, therefore, always necessary either to have capabilities to alleviate the consequences of a war or at least to be able to create capabilities in a short period of time. In general, adequate civil defense capabilities cannot be created in a short period of time unless extensive preparations have been made.

A rather important and valuable effect of a realistic civil defense program (and one that is often overlooked) is a psychological one. If one is designing his military establishment to terminate a war, rather than just to deter one (by

punishing the enemy with a retaliatory strike), one is much less likely to indulge in wishful thinking. Even today, without any disarmament schemes, Western military organizations and their governments have psychological and motivational difficulties in maintaining a high operating state of readiness and adequate combat capabilities. This is partly because many feel both that such weapon systems will never be used, and that if they were used they would be so destructive that you don't really care if they operate well or badly. If this attitude is combined with the moral onus on military preparations and planning that a disarmament agreement might bring one could almost confidently predict an undue and possibly dangerous degradation of Western military capabilities. If one is emotionally committed to the belief that deterrence is foolproof, there is not much of a step from being satisfied with a system which is objectively capable of destroying the enemy in a rataliatory blow to a system which can only hurt the enemy, and from there to a system which might hurt the enemy, and finally to one for which there are circumstances in which it is conceivable that the enemy will be hurt. The capacity of Western governments and peoples, under propitious circumstances, to indulge in wishful thinking in the military field is almost unlimited. An official aim which calls for an objective capability to terminate a war in a reasonably satisfactory fashion might have a salutary effect in restraining fancies. (W. W. Marseille has suggested to the author that "this is putting the cart before the horse. The psychological factors are what cause us not to have a realistic civil defense program in the first place." However, the author has found—to his surprise—that once people start thinking in terms of alleviating a war it is possible to successfully make points which it should have been possible to make if one were only arguing deterrence, but which were not taken seriously in this latter context.)

A PROPOSED CIVIL DEFENSE PROGRAM [3]

Once one accepts the proposition that it is possible to alleviate, to some extent, the consequences of a thermonuclear war, one is faced with the question, "Is it worth spending money on such a capability?" [3]

1. The creation of incomplete but worthwhile capabilities by reorienting and strengthening the current civil defense program utilizing feasible evacuation measures, improvised fallout protection, damage control, modest preparations for recuperation and, giving these other measures, the institution of a vigorous program of education and technical assistance to private parties and organizations. Some inexpensive measures might save from 20 to 50 million lives, limit the contingent damage to property, markedly facilitate our ability to recuperate, and provide an environment in which private citizens could do sensible things on their own to increase their chances of survival.

2. Research and development on all important aspects of the art of nonmilitary defense. Unlike research and development on military matters, nonmilitary defense has received comparatively little money and effort. In particular, the little work necessary for this study indicated that imaginative work could not only result in large improvements in the effectiveness of defense measures, but could also uncover many unsuspected problems that would otherwise be very unpleasant surprises.

3. Accompanying the research and development work should be a vigorous effort on the systems design of various combinations of military and nonmilitary defense. This effort should produce specification, including phasing, of many alternative programs. These specifications should be of sufficient detail to permit their costing and their performances to be caluculated over time and under many circumstances. Paper planning and design should be undertaken for a number of the alternatives specified so that any program finally adopted

---

[3] Most of the material in this section came from the Rand Corp. Report RM2206–RC, "Some Specific Suggestions for Getting Early Nonmilitary Defense Capabilities and Initiating Long-Range Programs," by Herman Kahn et al. That report was originally prepared in the early part of 1958, and was circulated in a limited fashion to various individuals for information and comment. While I have made some minor modifications in the material to correspond to some changes in my viewpoint, there has been no thoroughgoing revision. The dollar recommendations should be thought of as quantitative expressions of intuitive judgments. However, I should also note that I probably have substantially more justification for my estimates than do many official proposals. In any case, these things are so uncertain, and for reasonable programs the overall performance variations with minor changes in allocations are so small, that as citizen, voter, and taxpayer I am prepared to defend the numerical recommendations, even if as an analyst I have to concede that there is incomplete documentation.

would be less costly and have its leadtime reduced (by perhaps 3 to 5 years over conventional methods of proceeding).

4. While it is technically feasible to start a large-scale program of nonmilitary defense now, there are many uncertainties and gaps in our knowledge. After objectives 2 and 3 (research and development and leadtime reducing measures) have been accomplished, the proper balance between military and nonmilitary expenditures can be studied. The Government could then make wiser decisions, and some of the difficulties resulting from a combination of ignorance and uncertainty would be eliminated or decreased. The decision to go ahead or not go ahead with a multi-billion-dollar program should not be made until objectives 2 and 3 have been carried out.

5. There seem to be many possibilities for inexpensive preparatory actions that could result in the creation of important capabilities in the 1965–70 time period. Again, irrespective of any decision to go or not go into a multi-billion-dollar program, these possibilities should be studied; if and when such actions are found desirable they should be put into practice.

A possible allocation for the additional $500 million to be spent on civil defense might go as follows: (THIS was what Kennedy did in 1961.)

1. Radiation meters	[1] $100,000,000
2. Utilization of existing structures for fallout protection	[1] 150,000,000
3. Preliminary phase (including research and development) of a spectrum of shelter programs	75,000,000
4. Movement, damage control, and anticontamination, etc	[1] 75,000,000
5. Systems studies and planning	20,000,000
6. Other research and development	20,000,000
7. Prototype shelters	20,000,000
8. Education and technical assistance	20,000,000
9. Miscellaneous	20,000,000
Total	[1] 500,000,000

[1] Indicates Federal expenditures that would likely be supplemented by non-Federal expenditures stimulated by the program.

The above program can be divided into two parts: a short- and a long-range program, though there is a lot of overlap and joint use in the two programs, which is the reason why we do not budget them separately.

About 60 to 70 percent of the above $500 million would be spent to purchase capabilities that would be useful if a war started in the immediate future. Because the possible gains are so large, I do not believe that it is necessary to justify spending such a relatively small sum of money, even though there are some uncertainties about the performance of the program. The sum of $300 million is very small if it can make the difference between a relatively expeditious recovery for the survivors of a war and one that might not only be slow but could conceivably not occur at all; or if it could buy the kinds of capabilities that would make the difference between the Russians being able or not being able to blackmail us.

About 30 to 40 percent of the $500 million in our proposed budget, or less than $200 million, is allocated to research analysis, development, planning, and design for a spectrum of civil defense programs. This may seem to be a great deal of money to spend on producing pieces of paper and prototypes. But I believe that $200 million is a reasonable sum of money to spend on finding out how best to secure the lives and property of the Nation, and I would regard the proposed research program as a mandatory precondition to the decision to spend or not spend any large sums on passive defense itself.

Is $200 million really an unreasonably large sum? It costs from $50 to $100 million to develop an engine for a military airplane. It costs $100 to $200 million to develop an interceptor aircraft and $500 million to $1 billion to develop an intercontinental bomber. The ICBM development program cost between $1 and $2 billion. The Department of Defense spends $5 billion every year on research and development. We are saying that a complete nonmilitary defense program is at least as complicated as an interceptor aircraft.

We should also ask if $200 million is too little to be spending on long-range programs. Some people suggest the immediate initiation of large-scale passive defense programs that would cost in the neighborhood of $25 billion. It is improbable that very large sums could be spent efficiently on construction in the next year or two, and it is almost certain that if the attempt were made

without a prior program of the sort we are suggesting that not only would the wrong sorts of personal protection be procured, but there would also be major, maybe disastrous, inadequacies and lacunæ in the overall program.

We should consider the initiation of some inexpensive measures during the course of, and based on the results of, the research program. For example, circumstances might suggest a large "Starter Set"—including procurement of such materials as appear most likely to cause bottlenecks in a larger program: reinforcing steel, corrugated steel, structural steel, cement, and other building materials. If this were done, there would be no lag in the completion date of even the largest programs even though no major construction were begun immediately.

A decision to go ahead or not go ahead on a multibillion-dollar program should be made sepaartely from and subsequent to the completion of the proposed $200 million research program.

Still addressing ourselves for the moment to the proponents of large programs, there is at least one good reason why the Government may now be loathe to make a commitment for shelters. The shelter program itself has been looked at in only a superficial way, and many of the other problems associated with preserving a civilization and a standard of living have not been looked at even superficially. While our study tried to look at these overall problems and, in particular, to ask the question, "How does the country look 5 or 10 years after the war as a function of our preparations?" we scarcely scratched the surface. We believe we have shown that it is plausible, at least in the immediate future, that with inexpensive measures the United States could be an acceptable place to live even a year after the war. However, we concede that the uncertainties are large enough to raise the question of sheer survival, and the problem gets more severe in the later time period. Until the feasibility of recovery and other long-term problems and their solution are settled, it will be hard to arouse real interest in attempts to alleviate the consequences of war. But it is possible to settle these questions relatively inexpensively and at the same time avoid delaying the completion date for a full program or the immediate acquisition of moderate capabilities. The $200 million of our civil defense budget should be spent over a period of 2 or 3 years on what might be called the "cheap" starter set—the preliminary phases of a civil defense program—mostly on research, development, analysis, planning, and design.

These preliminaries should not be restricted to any prechosen program. The scale of the final program will presumably be determined by the results of these investigations and the current international situation; it should not be fixed prematurely. It is also most important to consider explicitly time period in the late sixties and early seventies. Unless we start soon the long-range programs needed to ameliorate the effects of potentially very destructive attacks of this time period, we will find that we have irrevocably lost very valuable opportunities.

Our goal in allocating funds to projects was not that every dollar be spent economically, but rather to make sure that every subject be covered adequately. While we were generous, we tried to refrain from padding. Although our figure of $200 million is, of course, only approximate, it is as likely to be low as high if an adequate job of research, development, systems analysis, planning, and design is to be undertaken. Many of the potential civil defense programs are so expensive that it is worthwhile to spend some money speculatively if there is any chance at all of the overall program being helped by even a small percentage. Therefore, the aim should not be to see that every dime is spent on the assurance that it will result in a successful project, but rather to see that all interesting avenues are explored. Otherwise, there may be disastrous inadequacies or even complete lacunae in the program that is finally adopted.

Such a large and many-sided program of study, planning, and innovation require a strong monitoring effort of a sort that is not common in most Government agencies. This effort has to be much more than the ordinary R. & D. administration. The monitors must maintain a continuous and close observation of all the programs and constantly evaluate their direction and results. While they should be able to suggest the termination of fruitless programs, their main purpose should be to encourage the expansion of promising effort. Most important, they must be alert to identify gaps and inadequacies in the programs, and suggest remedial action.

Because of their crucial role, the monitors must obviously be an exceptionally competent and well-informed group of people. However, the monitors do not need and should not have the authority to orient all programs toward prede-

termined objectives. Experience has shown that attempts to conduct large and overcoordinated programs tend to create inflexibility and to stifle new, unproven ideas or independent approaches. Hence, the monitors should act as an advisory group rather than as a "research czar." But they must have the authority to make suggestions and offer criticism at all levels and have the right to contact the researchers or planners in the field.

The monitoring group could be located in the independent long-range planning organization, mentioned in chapter 2, part II, and act for the various Government agencies that will be principally concerned with the nonmilitary defense effort. Or, it could be a special group in OCDM or under the Presidential assistant for national security affairs. In order to maintain a good "feel" for the program as a whole and to foresee future requirements, the monitors should be closely associated with the systems analysis and operations research program. Perhaps they should also have direct access to funds for small studies or pilot projects.

THE FULL PROGRAM

A superficial description of the $500 million program follows. Somewhat more detail (of a very similar program) can be found in the previously mentioned Rand Corp. report, RM 2206–RC.

1. Radiation meters ($100 million)

Our program calls for 2 million dose-rate meters (at about $20 a meter), 10 million self-reading dosimeters (at about $5 a meter, including an allowance for chargers), and 20 to 50 million dosimeters (at about $1 to $2 a meter).

Only a portion of the meters would be distributed before hostilities. The rest would not be distributed until a "national emergency" occurred or until the postattack period, and they should be stored with this in mind. The final distribution of meters might go somewhat as follows: 500,000 dose-rate or survey meters to the large shelters (capable of sheltering more than, say, 50 persons); 1 million to outdoor workers of various types, such as farmers, prospectors, foresters, construction workers, and so on; 250,000 to individuals and organizations in various towns and cities;[4] and 250,000 to the working teams discussed below under item 4.

The self-reading dosimeters would be distributed approximately as follows: 2,500,000 to the work parties discussed under 4 below; 2,500,000 to the shelters, schools, and other places; and 5 million to the people who work out-of-doors in possibly uncontrolled environments. The $1 and $2 dosimeters would be issued to everybody who is in an even moderately hot area and is not working under completely controlled conditions. The total budget allocated above is more than $100 million, but we think the number of meters suggested could be obtained and distributed if the Government were to allocate only $100 million. The rest of the budget should be made up of stimulated expenditures for meters by local governments, private groups, and individuals.

2. Utilization of existing structures for fallout protection ($150 million)

We would expect about $50 million to be spent on identifying, counting, and labeling the various structures that either provide valuable levels of fallout protection as they now stand or that can easily be modified to do so. The rest of the money would be spent for such supplies as radios, minimal toilet equipment (such things as primitive as buckets), and possibly even minimum food supplies (candy bars, multipurpose foods and such), or materials for improving the protection of the shelter. The survey should include places that can be used as improvised fallout shelters with various amounts of advance warning—1 hour, 2 hours, 4 hours, 8 hours, 16 hours, 2 days, 2 weeks, and even longer. We should hope to get detailed plans for the different kinds of improvisations that are pissible as a function of the time which is available.

3. Preliminary phase (including research and development) of a spectrum of shelter programs ($75 million)

One of the most short-sighted things that OCDM has done is to reduce its expenditures on the study of blast shelters—just because it is not part of the current "national shelter policy" to have blast shelters. As I have tried to stress in these lectures, we just do not know today what we will want 5 or 10 years from now, and current programs and requirements should not overinfluence

[4] Something like this is being done by OCDM.

current research and development. We should not prejudge these unknown future desires of ours by not undertaking inexpensive preliminary work on many more things than we expect to procure. It is only by having a broad base of research and development that we can expected to understand our problems and be in a position to have a flexible procurement policy.

These last remarks have special point for research and development and even preliminary programing in the shelter field. It is clear that if the international situation had already deteriorated to the point where we felt there was a high probability that we would have to fight a war, we would be instituting a very luxurious shelter system, indeed. It may turn out that, given the possibilities for weapons development, a pure fallout system will not be adequate in the late sixties and early seventies. For these and other reasons, the shelter studies should investigate the many different levels of protection that would be compatible with programs of as low as $2 or $3 billion to programs as high as $200 billion.

A possible allocation for the $75 million we have allotted to shelters would be as follows:

Theoretical work in the response of structures	$1,000,000
Theoretical work in design	1,000,000
Basic designs	3,000,000
Experimental testing	15,000,000
Detailed study of:	
10 large cities	10,000,000
10 medium cities	5,000,000
10 towns and rural areas	5,000,000
Study of geology and underground possibilities	10,000,000
Study of nonpersonnel shelters	10,000,000
Special equipment	10,000,000
Miscellaneous	5,000,000
Total	75,000,000

4. Movement, damage control, anticontamination ($75 million)

The two main things we should hope to provide under this category are the capability to evacuate to improvised protection and the creation of a core of "reservists" that would be organized to facilitate the evacuation, the improvisation of shelters either pre- or post-attack, and that would also be useful in the immediate postattack and longer run rescue, decontamination, debris clearing, continuity of government, housing, and repair problems. There are at least 5 million people in the United States who have the proper skills for such work. We should sign up 200,000 of these people as part-time but paid cadres and many others as unpaid part-time cadres or just available volunteers. The 200,000 people might go through a 1-week or 2-week training course every year. In wartime, or in a tense preattack situation, we should plan to expand them by a factor of 5 to 20. Such an organization would probably cost about $500 per man per year, or about $100 million per year for 200,000 people. However, it would be practically impossible to spend more than $25 to $50 million in the first year or two when this group is being organized, and this is the amount in our budget. This cadre might be supplemented (or replaced) by the military reserves.

Another $25 to $50 million would go for all the measures that are needed to create different kinds of potentially useful evacuation capabilities. What money is left, probably around $10 to $30 million, would be used to study and implement the damage control measures that will be necessary to limit the bonus damage when cities, factories, and homes are abandoned, to control fires, and to provide some additional protection for some government or crucial commercial stocks. This last figure is very definitely an allotment and not an estimate.

5. Systems studies and planning ($20 million)

The program described to this point is composed mainly of interim measures that are intended to fill the gap until we can decide what our long-range plans should be.

Among the first things to be studied and planned for are the different kinds of nonmilitary defense systems needed for various situations, and how we can build in our programs large degrees of flexibility. We must design systems to be in a position to exploit favorable circumstances and to hedge against unfavorable ones. Probably the worst defect of civil defense planning today is that it tends to concentrate on a single set of assumptions and circumstances (a surprise

attack directed at civilians), a set that also happens to be the most difficult to handle. As a result, civil defense recommendations have not been tested against a large number of possibilities. The proposed plans should not only consider a large range of circumstances, they should also consider phasing problems so that we will get early capabilities and still be able to accommodate growth in the future—particularly growth required by either unexpectedly large threats or higher standards. Some of the situations that might be studied are listed below:

(*a*) Movement of the population to shelters, considering warnings of minutes, 1 to 3 hours, 10 to 20 hours, and strategic evacuation.

(*b*) The various attack-response patterns (suggested in the lectures).

(*c*) Enemy tactics corresponding to three possible enemy target objectives: military, population, and recuperation—or mixtures of these.

(*d*) Civil defense postures as influenced or determined by many things, including variations in our own or enemy objectives, budget levels and allocations, disarmament, degrees of tension, changes in NATO, Chinese developments, other Russian satellite developments, and so on.

(*e*) Other strategic and tactical considerations; for example, sneak attacks and other unconventional tactics, unconventional weapons, reattacks, and various ways that war can be terminated.

(*f*) Worldwide planning.

(*g*) Basic technical uncertainties to be studied and allowed for include the performance and effects of weapons, carriers, air defense systems, medical unknowns, and so on.

In addition, all studies should be conducted with an eye to understanding and exploiting interactions between military and nonmilitary defenses. Some areas in which these interactions occur, and some proposed research projects, are listed below:

(*a*) The circumstances in which wars can start should be examined to determine what roles can be played by augmentation abilities brought into play in tense situations, on D-day, or even after D-day. For the starter set our military prewar mobilization capability is important. Lastly, and most important, we must reexamine our capability of fighting for days or weeks.

(*b*) Civil defense contributes to the overall problem by reducing the job of air defense and air offense to manageable proportions: by making large military budgets more acceptable (fighting and winning a war takes more military power than is needed for pure deterrence); by making safer use of nuclear weapons in air defense; and by protecting important elements of our air defense and air offense capabilities.

(*c*) On the military side, air defense provides warning, increases the enemy's raid-size requirements (even for minimum-objective attacks), forces him to use expensive carriers and tactics, cuts down his force, decreases his bombing accuracy, and may provide time against ICBM attacks by killing the first few missiles so people can get into shelters.

(*d*) Air offense (and effective civil defense) forces the enemy to buy expensive defenses (by making a U.S. first-strike credible), draws his attacks (particularly his first strike) away from population and recuperation targets, ends the war quickly either by destroying the enemy or forcing him to negotiate, and complicates the enemy's job by being dispersed, hard, and alert.

It might be appropriate at this point to comment on some of the characteristics of good analyses and plans. The following is quoted from RM–1829[5] "Techniques of Systems Analysis," by Herman Kahn and Irwin Mann.

"An item of equipment cannot be fully analyzed in isolation; frequently its interaction with the entire environment, including other equipment, has to be considered. The art of systems analysis is born of this fact; systems demand analysis as systems.

"Systems are analyzed with the intention of describing, evaluating, improving, and comparing with other systems. In the early days many people naively thought that this last meant picking a single definite quantitative measure of effectiveness, finding a best set of assumptions, and then using modern mathematics and high speed computers to carry out the computations. Often their professional bias led them to believe that the central issues revolved around what kind of mathematics to use and how to use the computer.

---

[5] A Rand Corp. report.

"With some exceptions, the early picture was illusory. First, there is the trivial point that even modern techniques are not usually powerful enough to treat even simple practical problems without great simplification and idealization. The ability and knowledge necessary to do this simplification and idealization is not always standard equipment of scientists and mathematicians or even of their practical military collaborators.

"Much more important, the concept of a simple optimizing calculation ignores the central role of uncertainty. The uncertainty arises not only because we do not actually know what we have (much less what the enemy has) or what is going to happen, but also because we cannot agree on what we are trying to do.

"In practice, three kinds of uncertainty can be distinguished:

"1. Statistical uncertainty.

"2. Real uncertainty.

"3. Uncertainty about the enemy's actions.

"We will mention each of these uncertainties in turn.

"*Statistical uncertainty.*—This is the kind of uncertainty that pertains to fluctuation phenomena and random variables. It is the uncertainty associated with 'honest' gambling devices. There are almost no conceptual difficulties in treating it—it merely makes the problems computationally more complicated.

"*Real uncertainty.*—This is the uncertainty that arises from the fact that people believe different assumptions, have different tastes (and therefore objectives), and are, more often than not, ignorant. It has been argued by scholars that any single individual can, perhaps, treat this uncertainty as being identical to the statistical uncertainty mentioned above, but it is in general impossible for a group to do this in any satisfactory way.[6] For example, it is possible for individuals to assign subjectively evaluated numbers to such things as the probability of war or the probability of success of a research program, but there is typically no way of getting a useful consensus on these numbers. Usually, the best that can be done is to set limits between which most reasonable people agree the probabilities lie.

"The fact that people have different objectives has almost the same conceptual effect on the design of a socially satisfactory system as the disagreement about empirical assumptions. People value differently, for example, deterring a war as opposed to winning it, or alleviating its consequences if deterrence fails; they ascribe different values to human lives (some even differentiate between different categories of human lives, such as civilian and military, or friendly, neutral, and enemy), future preparedness versus present, preparedness versus current standard of living, aggressive versus defensive policies, etc. Our category, 'real uncertainty,' covers differences in objectives as well as differences in assumptions.

"The treatment of real uncertainty is somewhat controversial, but we believe actually fairly well understood practically. It is handled mainly by what we call contingency design

"*Uncertainty due to enemy reaction.*—This uncertainty is a curious and baffling mixture of statistical and real uncertainty, complicated by the fact that we are playing a non-zero-sum game.[7] It is often very difficult to treat satisfactorily. A reasonable guiding principle seems to be (at least for a rich country), to compromise designs so as to be prepared for the possibility that the enemy is bright, knowledgeable, and malevolent, and yet be able to exploit the situation if the enemy fails in any of these qualities.

"To be specific:

"To assume that the enemy is bright means giving him the freedom (for the purpose of analysis) to use the resources he has in the way that is best for him, even if you do not think he is smart enough to do so.

"To assume that he is knowledgeable means giving the enemy credit for knowing your weaknesses if he could have found out about them by using reasonable effort. You should be willing to do this even though you yourself have just learned about these weaknesses.

"To assume that the enemy is malevolent means that you will at least look at the case where the enemy does what is worst for you, even though it may

---

[6] "The Foundations of Statistics," by L. J. Savage; "Social Choice and Individual Values," by K. J. Arrow.

[7] The terminology "non-zero-sum game," refers to any conflict situation where there are gains to be achieved if the contenders cooperate. Among other things, this introduces the possibilities of implicit or explicit bargaining between the two contenders. The whole concept of deterrence comes out of the notion that the game we are playing with Russia is non-zero-sum.

not be rational for him to do this. This is sometimes an awful prospect and, in addition, plainly pessimistic, so one may wish to design against a 'rational' rather than a malevolent enemy; but as much as possible, one should carry some insurance against the latter possibility."

6. Other research and development ($20 million)

This is for miscellaneous research in the medical, biological, food, agricultural, anti-contamination, and fallout areas. The AEC currently spends about the allotted sum every year to study the inherently simpler problem of peacetime fallout from tests. The equally important special wartime problems are mostly being neglected.

7. Prototype shelters ($20 million)

We would suggest building about 10 million dollars' worth of large shelters which, if economically feasible, might include some peacetime functions. In addition to "customary" shelters, this program should include more elaborate shelters and high overpressure shelters. The other $10 million should go for private family-type shelters, running an average of, say, $1,000 apiece. This should enable us to build 10,000 shelters, or 1 for every 20,000 people. This means that every town in the United States would have at least one prototype shelter.

8. Education and technical assistance ($25 million)

It is one of the major objectives of the above program to create an environment in which private citizens and organizations can do sensible things on their own. The main way the Government can encourage this is to do enough on its own so that people will see that if they supplement the Government's efforts they will either improve their chances for survival or the style in which they survive. Many of the preceding suggestions are aimed at making it possible for the Government to furnish realistic technical information and planning assumptions. This will enable those that wish to, to do sensible things on their own.

We feel that at least part of the present apathy in the United States is due to ignorance of what can be done or to doubt that anything can be done. This apathy is intensified by the inadequacy of official pamphlets. The problem does not result from security restrictions or inadequate releases of information; official studies themselves are inadequate. Better studies and more definitive Government programs are needed. Realistic long-range planning, such as we are proposing, would go far toward restoring public confidence in the merits of Government plans and suggestions. Even more effectively, the institution of the "cheap" program, which depends mainly on improvised fallout shelters, would encourage many to build more adequate shelters on their own. As long as there is no reasonable overall program, few will undertake private actions.

In addition to general information, the Government should offer to share some of the private expenses. However, because of the small size of the program, the Government should not contribute anything toward private projects unless it gets a great deal of leverage for its money. One of the easiest ways to get such leverage would be for the Government to spend small sums of money on the preliminary phases of the private projects; that is, it should be willing to go to a private company with a complete set of blueprints showing that company what it would have to do if it participated in a serious way in such a program. This would enable the company, without spending any of its own money or much energy, to get very specific ideas of the cost and performance of its own program. It would help eliminate the inertia that might otherwise prevent companies from initiating any actions. The Government should do similar things for private persons, not only by furnishing complete blueprints for either the modification of existing buildings or for the incorporation of protection in new buildings but also by offering technical assistance in their construction. It should also furnish services to architects, engineers, and others.

In addition to helping private companies and individuals, the Government should try to elicit as much help from the nongovernmental part of our society as it can. For example, once the research program has provided some indication of what a reasonable passive defense program should involve, the Government should enlist the help of private professional groups to expedite some of the

necessary intellectual and technical developments. Some of the organizations whose aid might be solicited include:

American Society for Civil Engineers.
American Concrete Institute.
American Bar Association.
American Medical Association.
American Institute of Architects.
National Planning Association.
Committee for Economic Development.
Chambers of commerce.
National Bureau of Economic Research.
American Association of Railroads.
American Society for Testing of Materials.
American Society for Mechanical Engineers.
American Society for Electrical Engineers.
American Society for Heating and Ventilating.
National Association of Manufacturers.

In the past, private groups have sometimes put time and energy into studies for the Government, but a lack of adequate orientation has often meant that their studies were obsolete before they were started. It is important, both for the morale of the participants and the usefulness of their product, that realistic environments and planning assumptions be given to such groups. For example, the American Society of Civil Engineers (ASCE) is reported to be considering a standard for the protection of buildings in large cities on the order of 5 to 10 pounds per square inch. Such buildings might not be useless in some situations, but they would certainly be useless if bombs dropped nearby. We would propose that a much more useful activity for the ASCE would be to look at joint-use, blast-resistant construction for small cities and rural areas rather than for large cities. An even more useful thing, and one which we would urge be done with a high priority, would be to look at the possibilities for joint-use fallout protection, both with and without warning (hours or days). For example, buildings might be built to use sandbags or fillable shutters that could be put up at the last moment. Either of these would greatly decrease their vulnerability to radiation. We feel that the possibilities are so promising that an appreciable portion of an expensive fallout program might be saved (though only a portion). It is clear there are many other examples where private organizations could be useful. Universities and foundations, for example, could make major contributions.

It is with some reluctance that I include education in the program. This is not because education is not a very important thing. In particular, in a program that depends a great deal on improvising existing assets, it is probably very important for many people to understand reasonably well what they should do. However, the Government has a tendency to try to depend upon education and paper plans to do everything, rather than to spend even small sums for capabilities that would make the educational program realistic and useful. It is not going to be true that our society can be preserved in a war by individual action supplemented only by Government pamphlets and paper plans. I suspect that the major educational impact will come, not from the formal program of information or propaganda, but simply from the impact of the Government's allotting reasonably large resources to a program that it is willing to defend intellectually. This alone should make many people understand that the program is a serious effort and that one does not have to be a "crackpot" or "wishful thinker" to join in. Conversely, if the Government tries to accomplish this program by education alone, if it is unwilling itself to invest a few hundred million dollars and thereby shows that it has little confidence in the effort, then, I think, we should not be surprised if the program fails completely.

It may, of course, turn out that the Government does not wish to engage in a program as ambitious as the one described, modest as it may seem to those of us in the planning field. In that case, we suggest that the Government try at least the following:

1. Reorient Government planning, both military and nonmilitary, to the proper kind of short and long wars; in particular, make explicit preparations for improvising preattack and postattack capabilities.
2. Reorient current stockpile programs to contribute to postwar survival recuperation.
3. Reorient and strengthen civil defense programs to pay particular attention to those situations in which their capability is most applicable rather than try to handle all problems across the board.

4. Broaden the current programs of research, development, and systems analysis to consider in more detail the problems involved in recuperation and in the postwar period generally.
5. Study and propose legislation now to facilitate postwar economic stabilization and recuperation.
6. Initiate research and study in the use of mines as personnel and industrial shelters.
7. Initiate a program of technical education and assistance to orient and encourage private actions planning and research.
8. Do much more long-range planning in the field of nonmilitary defense and independent and dependent groups. In particular, we suggest that OCDM or the executive department establish a permanent long-range planning organization of the same type as Rand, ORO, or the like.

Three Lectures on Thermonuclear War (1960–75) by Herman Kahn

LECTURE I. THE NATURE AND IMPACT OF VARIOUS KINDS OF THERMONUCLEAR WARS

This lecture asks the question, "Is it really true that only an insane man would initiate a thermonuclear war or are there circumstances in which the leaders of a country might rationally decide that war is preferable to any of its alternatives?"

It is concluded that there are plausible, even probable, circumstances in which a country may rationally decide on war as its best alternative. In arriving at this conclusion it is convenient to examine eight distinct phases of a thermonuclear war.

1. Various phased programs for deterrence and defense and their relations to foreign policy.
2. Wartime performance with different preattack and attack conditions.
3. The acute fallout problems.
4. Survival and patchup.
5. Maintenance of economic momentum.
6. Long-term recuperation.
7. Long-term medical problems.
8. Genetic problems.

LECTURE II. THE FORMULATION AND TESTING OF STRATEGIC OBJECTIVES AND WAR PLANS

This lecture asks such questions as, "Why and how might a thermonuclear war be initiated? How might it be fought and terminated?"

In discussing these questions it is desirable to distinguish at least three kinds of deterrence:

Type I—The deterrence of direct attack (passive deterrence)
Type II—The deterrence of extreme provocations (active deterrence)
Type III—The deterrence of moderate provocations (tit for tat deterrence)

The requirements for the three kinds of deterrence, their interactions, some of the strains to which they might be subjected, and the probability and possible consequences of failure are discussed. Finally, criteria are set up for different circumstances and objectives to be used in the design and testing of the composition and posture of strategic forces. These are listed below:

Seven basic situations:
- A. Nontense:
  1. Premeditated Soviet attack
  2. Unpremeditated war
- B. Tense:
  1. Premeditated Soviet attack
  2. Unpremeditated war
  3. Premeditated U.S. attack
- C. Mobilization and legacy
- D. Arms control and violation

Attackers' objectives:
- A. Limit damage
  1. Counter force
  2. Postattack blackmail
  3. Civil and air defense
- B. in war
- C. in peace

Peacetime objectives:
- A. Type 1 deterrence
  - 1. Quality needed
  - 2. Second strike capability
  - 3. Attackers' defense
- B. Type 2 deterrence
  - 1. Necessity
  - 2. First strike capability
  - 3. Non-alert capability
- C. Not look or be too dangerous
  - 1. To us
  - 2. To allies
  - 3. To neutrals
  - 4. To enemy

Defenders' objectives:
- A. Punish enemy
  - 1. Priority affected by damage accepted
  - 2. Population and recuperation targets
- B. Stalemate war
  - 1. Conflicts with punish enemy
  - 2. Requires staying power
  - 3. Feasibility varies
- C. Limit damage

LECTURE III. WORLD WAR I THROUGH WORLD WAR VIII

Some characteristics of eight wars, real or hypothetical, are analyzed, partly to show relations between strategy, tactics, and technology; and partly to illustrate certain historical themes or possibilities. The eight wars, each a technological revolution ahead of its predecessor, are assumed to have occurred as follows: 1914, 1939, 1951, 1956, 1961, 1965, 1969, and 1973. The historical themes associated with each war are listed below:

1914—An accident prone world miscalculates. Expectations are shattered.

1939—Type II and type III deterrence fail. Expectations are shattered.

1951—A militarily superior nation risks disaster.

1956—Type II deterrence wanes.

1961—The Soviet Union attains "parity." Type II deterrence disappears. Type I deterrence is marginal.

1965—The prematureness of "Minimum deterrence."

1969—Possibility and consequences of "Minimum deterrence." Arms control or "?"

1973—Fourteen years of progress (or 50,000 buttons).

Senator ANDERSON. I think it has been a most interesting discussion. We will resume the afternoon session at 2 p.m., in this room, with testimony from Commissioner Willard F. Libby of the Atomic Energy Commission on emergency protection measures.

Following his testimony there will be a panel of the following individuals who will discuss the strategic implications of deterrence: Dr. Willard F. Libby, Comissioner, U.S. AEC; Mr. Robert Corsbie, Director of Civilian Effects Test Group, AEC; Dr. Paul Tompkins, NRDL; Mr. Herman Kahn; Mr. W. E. Strope, NRDL.

I hope you can be here at 2 o'clock.

Mr. KAHN. Thank you, sir.

(Whereupon, at 12:30 p.m., the hearing was recessed, to reconvene the same afternoon at 2 p.m.)

AFTERNOON SESSION

Chairman HOLIFIELD. The committee will be in order.

Just before the noon recess we heard from Mr. Herman Kahn, who testified in advance of his position on the agenda in order to accom-

modate Dr. Willard F. Libby, U.S. Atomic Energy Commissioner, who will speak to us on the subject of emergency protection measures.

After Dr. Libby's testimony is heard and the question and answer period we will have a panel discussion on the strategic implications of deterrents. On that panel we will have Dr. Libby, Dr. Robert Corsbie, Director of Civil Effects Test Group, Dr. Paul Tompkins, Naval Radiation Laboratory, Mr. Herman Kahn and Mr. W. E. Strope of the Navy Radiological Defense Laboratory.

At this time Dr. Libby, I think the Chair should say a few words. You have served as Atomic Energy Commissioner now since the 5th of October 1954. Your term is expiring on June 30 and you have told me that you are going out to my State of California and teach chemistry out there in the University of California at Los Angeles.

Dr. LIBBY. That's right, Mr. Holifield.

Chairman HOLIFIELD. This committee has had you before it many, many times. You have testified many hours. There have been times when some of the members at least have disagreed with you, but most of the time I think most of the members agreed with you. But whether it was agreement or disagreement, our exchange of views has always been pleasant. We realize it is your own desire to return to the atmosphere of the campus again. However, it would be remiss on my part if I did not express, and I believe I am expressing the feelings of all the members of the Joint Committee on Atomic Energy, our thanks to you and our deep appreciation for the many years you have served in the position of Atomic Energy Commissioner, for the untiring effort and the many contributions you have made to the understanding of the American people in this highly complicated and technical field.

So as you go into private life, the good wishes of this committee go with you. We wish you the very best and we are happy that we have had an opportunity to have you once again before us to testify on something which I know is dear to your heart.

Mr. Vice Chairman?

Representative DURHAM. Mr. Chairman, I want to concur first in the statement of the chairman of the subcommittee and also to say to Dr. Libby I think he has rendered valuable service to the American people over the years he has served as Commissioner. Certainly he has enlightened this committee. He is a great scientist. About the only exception I would take to your statement, Mr. Chairman Holifield, would be that my desire would be that he go to my State and my own city of Chapel Hill to impart the information that he has in that great brain of his to students. Of course, I am sure that California will benefit from his presence there. We will miss you, Dr. Libby.

STATEMENT OF DR. WILLARD F. LIBBY,[1] COMMISSIONER, U.S. ATOMIC ENERGY COMMISSION

Dr. LIBBY. Thank you, Mr. Holifield and Mr. Durham. I hope that if there is ever anything I can do for the committee you won't hesitate to ask me.

---

[1] Date and place of birth: December 17, 1908, Grand Valley, Colo. Education: Bachelor of science, University of California, 1931; doctor of philosophy (chemistry), University of California, 1933; Work history: Instructor of chemistry, University of California, 1933–38; assistant professor, 1939–43; associate professor, 1943–45; professor instructor nuclear studies, Chicago, 1945–54; member, General Advisory Commission, AEC, 1950–54; member AEC, 1954—.

Representative PRICE. Mr. Chairman?

Chairman HOLIFIELD. Mr. Price.

Representative PRICE. If the other members fail to say anything Dr. Libby, it is only because they agree fully with the statement of the chairman and Mr. Durham.

Representative HOSMER. I wish to concur in that completely. It goes almost without saying, our respect for your integrity, for your knowledge and for the wisdom of the advice that you have generously offered us.

We all wish you the best of luck.

Dr. LIBBY. Thank you, sir.

Representative HOSMER. I am particularly delighted because you are coming out to my part of the country as well as Mr. Holifield's.

Dr. LIBBY. Thank you, Mr. Hosmer.

Chairman HOLIFIELD. You may proceed, Doctor.

Dr. LIBBY. Mr. Chairman, in the testimony before this subcommittee you have been informed on the effects of a simulated attack on our Nation with nuclear weapons delivered by modern military methods.

The things an attack like this can do to us, the extent and the nature of the effects on people, livestock, crops and on our educational, social and governmental institutions call for energetic leadership and action.

A million of anything is a lot. When we estimate casualties in the millions, it is obvious that we face a possibility which requires priority attention.

There are relatively simple things we can do in preparation for the time of disaster which will make a tremendous difference in our response as individuals and as a nation.

The most effective way to reduce war casualties is to not have the war; and the national policy is to work continually toward conditions which lead to a lasting, just peace for all men.

We are led, when we review the history of man, ancient and modern, to the conclusion that it is wise to take out some insurance for our protection in the event that something goes wrong and peaceful international relations come to an end.

The nature of the effects of modern nuclear weapons and the ranges over which these effects can produce casualties may provoke the question: "Is there really anything we can do?" My answer to this question is, "Yes."

Now I am not going to sit here and tell you that there is a simple, cheap way to protect the people who are in the center of a target at the time it receives a direct hit.

If the weapon is large and accurately delivered, the closein results of the detonation are pretty well fixed.

But let us talk of the people located beyond the range of the initial effects. These people live everywhere in the Nation, in large towns and small, on the farms in rural areas.

We must remember that they also live in our large cities. All have available to them the courses of action which will increase the probability of their surviving and decrease the probability of their becoming sick or being injured.

The committee will recall that we have announced that the fallout from the March 1, 1954, detonation at Bikini Atoll would have created radiation casualties in an area estimated at 7,000 square miles if no protective measures were taken.

Casualties, seriously injured, and dead from the initial effects of this bomb would have occurred in an area of perhaps 250 to 300 square miles.

There is a great difference between the two areas and I should like to focus attention on the need for protection and the capability for protecting the people in the 6,700 square miles or more beyond the range of initial blast, thermal and nuclear radiation. We can save them easily. We can lose them easily.

As a case in point we may think of an attack on a hardened military installation in a sparsely populated area. The initial effects may inflict heavy damage on the facility and military implements.

The number of personnel casualties may be relatively low in number. But for hundreds of miles downwind—assuming surface bursts—the residual radiation will injure or kill those who are unprepared.

Thus a more densely populated area of little true military significance may find itself involved with the results of events occurring hours earlier many miles away.

That fact that you don't live in or near a potential target no longer gives you the sense of security you might have had when only conventional explosives were used.

And of course you have no control over the selection of targets.

Now what can we do?

The first action for anyone who does not already possess the knowledge is to learn what these weapons effects are. No one can be expected to act properly or at all for that matter on any problem unless he understands what makes it. It is necessary for people to learn about fallout, about nuclear radiation about the effects of nuclear radiation on people, animals, plants, food, water: The things that are immutably linked to life. In a larger sense, this is a matter of getting up to date which is essential to good citizenship in any circumstance.

The peaceful applications of nuclear energy and the use of radioactive isotopes will grow with the passage of time. An informed public must be ready to express its opinions on the new proposals.

In the open literature there is a wealth of information on effects. The news media are making a regular contribution. The record of these hearings will add to the store.

Nevertheless, more public information and education will be required until we begin to reach the point where surveys show that Americans know as much about nuclear effects as they do about such familiar natural phenomena as rain, wind, floods, and electrical storms and the rather complex and sometimes hazardous equipment we use every day.

So then first we must add to and reinforce the foundations of public knowledge on which will rest our survival and recovery actions.

Second, we must teach people what to do to keep from being killed or injured by these effects in time of war. Actually this goes hand in hand with public education so that a man learns of the hazard and countermeasures essentially at the same time.

Third, we must be ready to back up and support these people with technological developments which will improve the effectiveness of their defensive preparation.

This then is the defensive pattern:

(1) Tell the people what they may be up against.

(2) Tell them what actions are to be taken before, during and after an attack.

(3) Support their efforts with new information, new tools and devices and new techniques.

We are all bound up in this together. People as individuals, as families, as heads of corporations, as governmental leaders from the smallest community on up. We cannot merely give this assignment broadly to our citizens and to their civil defense directors and walk off and forget about it.

As with any job the people doing the work are going to need general support, outright assistance with difficult parts, and the stimulus that comes with knowing that someone else is interested and ready to pitch in.

If we are to accomplish anything there will have to be a certain amount of initiative all around. We must surely progress further beyond the talking and planning stages, thereby setting a good example for those who look to us for guidance.

The policy of providing fallout shelter in new Government construction is an example of a practice which may be observed and copied.

It has been widely stated, and it needs to be said many times more, that for a man to be able to guarantee a high degree of protection for his family he must have a fallout shelter. This can be as elaborate as he likes and can afford. It can also be skimpy if he prefers to gamble with lives. But if heavy fallout is deposited in an area, the best use of the best available shielding against the radiation is an absolute must if the inhabitants are to avoid unnecessary radiation exposure, illness and death.

While we ordinarily speak of this shielding as a shelter, and while we think that people are well advised to provide themselves with a suitable shelter, it remains a fact that many homes and buildings provide a life-saving amount of shielding in their basements as they stand. It is a matter of learning where to go for the best protection.

In May 1958 in Operation Plumbob we conducted a study at the Nevada Test Site to improve our knowledge of the shielding, and thus the protection, which you might find in typical residences.

I will say we, the AEC, OCDM and all of us working together. But the AEC takes a real interest in this study.

We used about 400 small radioactive cobalt sources encased in a plastic hose and arrayed about and over the structures to simulate the radiation field of fallout. We learned of the great possibilities of this technique and we learned some interesting things about the shielding in typical residences. (See charts 1 and 2.)

CHART 3

SHIELDING FACTORS OF TYPICAL HOMES

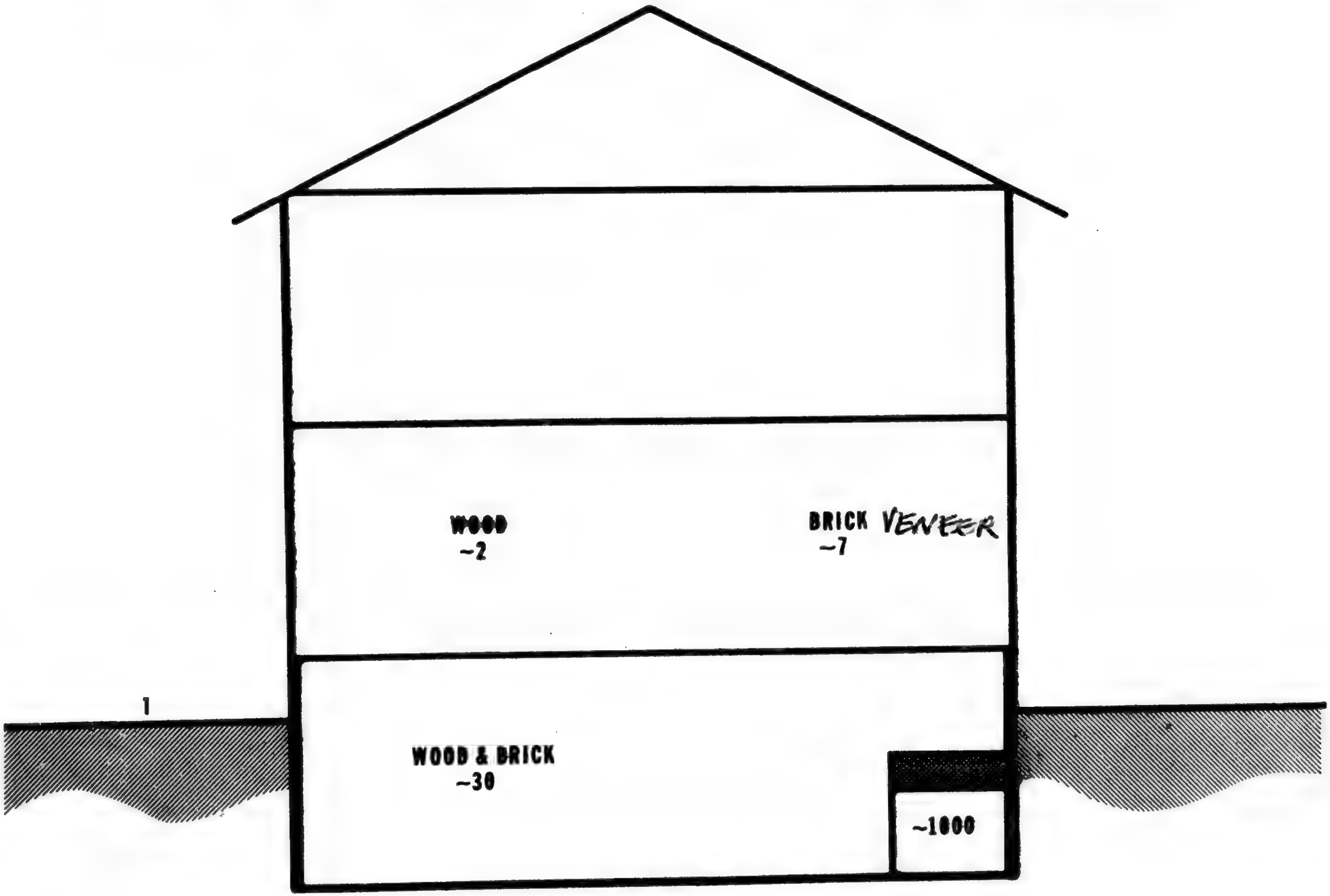


CHART 4

Cellar window, two-story brick house

CHART 5

Cellar window, two-story brick house, sandbagged

For example, it proved out that the most effective shielding material is that which is in the direct line of radiation.

On the first floor of a two-story wood building the average radiation was about one-half of that outside. On the first floor of a two-story brick building the average was about one-seventh. (See chart 3.)

A good many basements have windows and other openings which let the radiation in. By closing the openings with dense material like bricks or sandbags, the radiation level in the basement is reduced by a significant amount. (See charts 4 and 5.)

Kitchen and bathroom fixtures, bookcases, furniture, and closets cast shadows which give additional radiation protection. That is, these shadows are shadows of the fallout radiation.

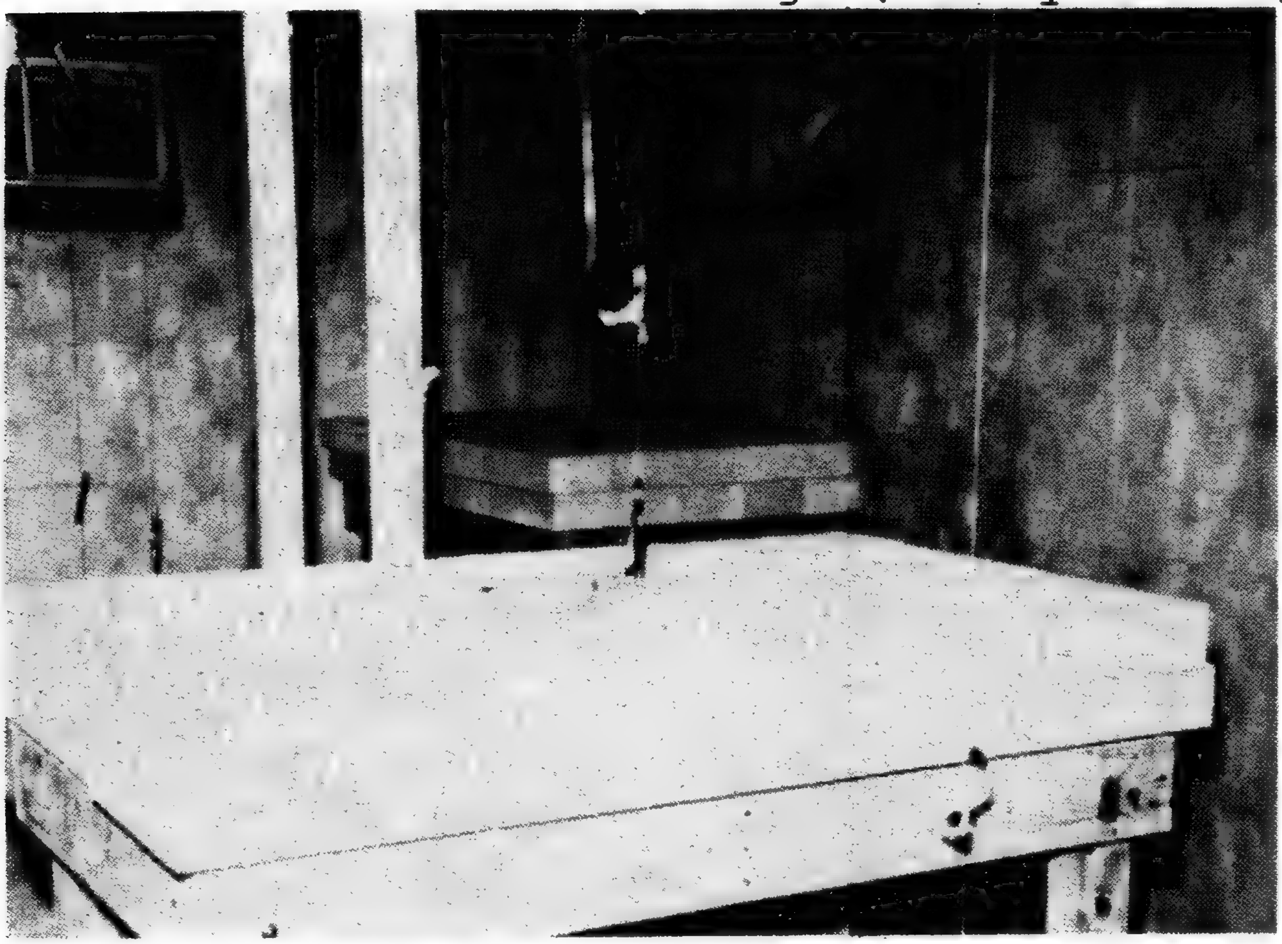
The location of the shelter area to take advantage of the shielding makes for a safer shelter.

Dose rates behind masonry chimneys and inside fireplaces are appreciably decreased.

The contribution of fallout on roofs of two-story houses to the dose rate on the first floor is less by a factor of 10 as you see from your second chart, than the contribution from the fallout on the ground outside the house.

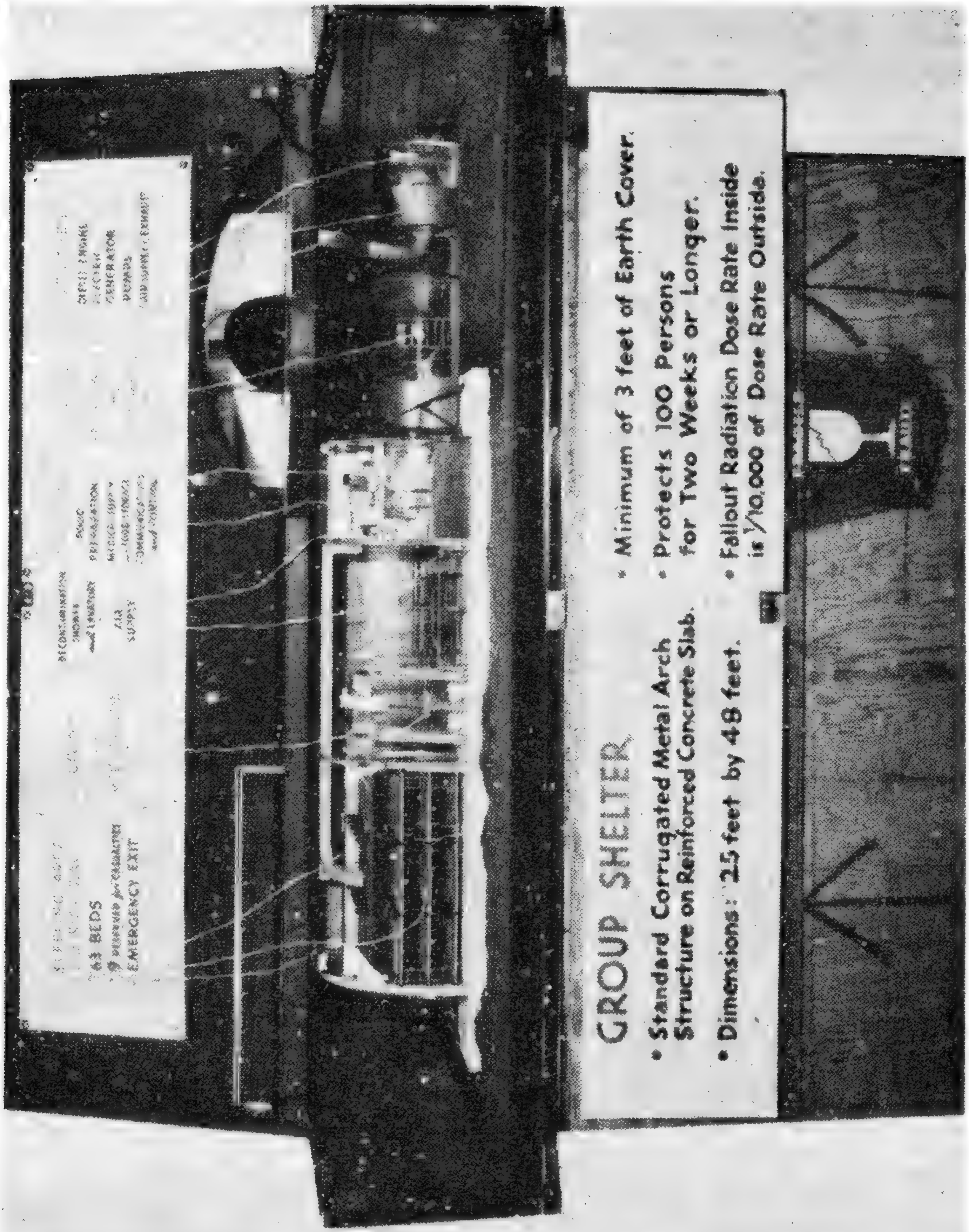
In the Nevada experiments a shelter was improvised of a heavy table placed in the corner of a basement and covered with 7½ inches of solid concrete blocks. (See chart 6.) Or boxes lined with water filled plastic bags (Kearny method)

CHART 6



Seven and one-half-inch concrete over table to provide improvised shelter in corner of basement and arrangement of intergrating dosimeters to measure radiation

CHART 8


63 BEDS
EMERGENCY EXIT
GROUP SHELTER
• Standard Corrugated Metal Arch Structure on Reinforced Concrete Slab.
• Dimensions: 25 feet by 48 feet.
• Minimum of 3 feet of Earth Cover.
• Protects 100 Persons for Two Weeks or Longer.
• Fallout Radiation Dose Rate Inside is 1/10,000 of Dose Rate Outside.

This was tested as a radiological shelter at the Nevada test site in Operation Plumbbob in 1957. It was located 1 mile from a detonation of about 20 kilotons, that is equivalent power of 20 kilotons, and was occupied by Mr. Corsbie and other people working on the project at the time of the explosion.

Three times, three detonations. Now in 2 of these detonations the fallout patterns close to 100 r. per hour fell right across the shelter as we had hoped it would. The blast pressure was 4 pounds per square inch. Now that is important because it is to be noted that in Hiroshima 35 percent of the casualties occurred at lower pressures than this.

Earlier tests demonstrated that the basic shelter would provide protection against as much as 25 pounds per square inch.

The radiation reduction factors was 10,000 or more, so it would seem that this shelter, that one could have a lot of confidence in this particular design. Now it may be described as a buried or mounted 25 by 48 foot metal arc structure as shown by the panel in the easel and in the model cutaway. It will accommodate 100 people for 2 weeks we hope.

I say we "hope" because we don't know as much about prolonged occupancy of a shelter as we do about providing fallout protection.

Engineering work on modifications to the shelter is nearing completion.

Mr. Corsbie's model here shows in considerable detail the kind of thing that is underway.

It is planned to make these changes to the shelter now in the ground at Nevada test site during the summer and then go to work on the matter of learning something about the problems of living in the shelter. I think we will all feel uncertain and uneasy about telling people to be prepared to stay in a shelter for a week or two until we know about what this means in terms of human habits and adaptation.

These experts are in a way like those described by Mr. Strope yesterday.

Representative HOSMER. Dr. Libby, has there been any analysis of the material the Navy acquired during its studies of confinement prior to the development of the Atomic submarine, the psychological matters run into?

Dr. LIBBY. Yes, but I think the problem is rather unique here. The geometry, the way you sleep, the freedom of movement is different from a submarine to a certain extent and we ought to really check it out. We like this shelter. We think it is practical, it is economic and it is useful, but this is a big unknown. Maybe people just can't stay in there 2 weeks, but we think they can.

During the tests of the shelter in 1957, we had personnel from various AEC operations offices come to the test site to participate in the experiment and to get some firsthand experience.

Thought is being given to similar participation in the human engineering experiments. In this manner we can inform the staffs in the field of the practical aspects of the program.

Also working with AEC and contractor personnel in the field, we shall start using at Oak Ridge late in June a radiological survey vehicle, commonly called a fallout truck.

ments for these are quite different. What is satifactory for one may not be satisfactory for the other. Second, I don't want to give the implication that we think that civil defense plays a role in military affairs in the classical sense of the word, by backing up the Armed Forces, supplying them with men, materials, and morale. In some real sense, civilians and cities are not much of a military target—this is oversimplified but you have to oversimplify.

Cities do contain such military assets as communications, municipal airports, off-duty personnel, and so forth, but I would doubt that all of the military assets in all of our cities are equivalent in military capability to a couple of wings of B–52's. You don't protect civilians today because they fight wars. You protect civilians because it is the job of the military to do that and not the job of the civilians to protect the military forces.

It is very important to realize this. Sometimes people forget it. Second, you protect civilians because unless you can do this you are vulnerable to blackmail, either before the attack, during the attack, or after the attack.

Representative HOSMER. How do you use the term "blackmail," Mr. Kahn?

Mr. KAHN. I use the word in the customary sense, where the other side uses threats to influence your behavior and maybe even to make you pay off.

We discussed earlier the possibility that if we cannot accept Russian retaliatory blows, and if it is clear to us, or the Russians, or the Europeans that we cannot accept them, then we may be in a very precarious position.

That is, you have to persuade all three simultaneously. Then we asked ourselves what do we mean by accepting a retaliatory blow, and we noticed the rather different views Europeans and Americans seem to have of the credibility of our initiating actions leading to that possibility. I have no information as to what the Russians would think, none at all.

This is preattack blackmail. The other kind of blackmail is a little too technical to discuss now but it is discussed in papers, as the so-called postattack blackmail. He can influence your behavior after the war is started.

Dr. LIBBY. Of course, in World War II, I think we learned that the whole Nation has to fight the war. That is, industry was an integral part of the effort, and certainly in that sense civil defense is part of it.

It may be even more directly a part of the effort than the heavy industry was in World War II.

But it seems to me not too extreme a position that civil defense is pretty closely related to our defense posture.

Mr. KAHN. I would like to make a partial exception to Dr. Libby's remark. Many people object to air and civil defense, not because they underestimate the problem, but because they overestimate it. They think there is nothing significant that can be done to alleviate the consequences of a war.

For example, if you examine most air defense studies done in the United States, say until about 2 years ago, it almost always turns out that one of the objectives of the study was to defend the war mobilization base.

Now you can't do that job, therefore if you believe that this is the objective you come up with the position why spend money on air defense or civil defense? There is, however, another question which is also important: "How does the country look 5 or 10 years after the war as a function of the prewar preparation?" For this question one does not ask, "Can we produce jet engines in the first year of the war?"

Now the first task cannot be done, but the second can. Therefore you are actually hurting yourself if you try to overstate the importance of civil and air defense by saying that we need the output of these factories to fight the war because you are then setting up an infeasible objective which automatically leads to apathy.

The problem is, "Can you do the much easier job?"

Dr. LIBBY. Yes; I think that is a very reasonable point. There is a psychology of action that is necessary rather than a psychology or an attitude of hypothetical and theoretical consideration.

If we could get citizens interested in a few things like basement shelters so that people had the feeling that they were doing something to improve their position, their attitude toward the civil defense operation might change, so that one of some hope might take the place of one of pretty general despair and hopelessness.

Mr. KAHN. May I add something to that?

If you expect people to have faith in these moderate preparations you have a right to ask that the Goverment have some faith in them too.

Chairman HOLIFIELD. Will you speak a little louder, please?

Mr. KAHN. If one expects the average American citizen to have faith in modest preparation like simple fallout shelters, 2-week food supplies, and so forth, one also has the right to ask the Government to have faith in these programs.

Conversely, if the Government shows that it does not believe that these modest measures will be effective, then how can we expect the citizens to believe in them?

The Government has obviously shown it does not believe in moderate measures because it supports them in a rather modest fashion to understate it.

Now we have looked at this problem, we have asked ouselves what is the minimum task you can ask civil defense to do, and we come up with two.

The first one would be to prepare what I called the B country, that is, the rural areas, small towns, and so forth, to survive and recuperate from a war in which the A country, the largest 50 to 100 cities were destroyed.

For at least the near future this is a relatively simple and feasible task and we don't think it costs very much to make these preparations. The second task that we think should be done is to have the capability to take the people of the A country and put them in places of protection in the B country on say 24 hours' notice. I am using the dirty word "evacuation." It is not wishful thinking to think of 24-hour evacuation capabilities as being useful.

It has nothing to do with the belief that we have a secret agent in Moscow to give us intelligence. It simply depends on the following: That as far as the Russians and the Europeans are concerned, they

will have a quite different attitude toward the resolution of the United States if they think that the United States can put its people in a place of protection given 24 to 48 hours' notice, than if they feel that even given a month's notice there is nothing we can do.

In other words, imagine yourself going into a Munich-type conference where the Russians had evacuated their cities and you had not. They may even have done it slowly, say over a period of a week, and now you have to bargain with them, and they are evacuated and you are not. You are going to have some very tough bargaining to do.

Chairman HOLIFIELD. Any comment, Mr. Strope, Mr. Corsbie?

Mr. STROPE. No. This was a point that I wished to be brought out and it has been brought out somewhat already. The concept of a country A and a country B is very useful. It is useful in civil defense because the problems of defense are completely different in the two countries.

Protecting country A is a very difficult problem. Protecting country B is a very reasonable problem. I think the question which is most important right at the moment is: Suppose we have made country B impregnable in the face of a Russian thermonuclaer threat. How does this change or how does this affect our general posture in deterring a war?

I think that Herman has considered this at quite considerable length.

Chairman HOLIFIELD. Mr. Corsbie?

Mr. CORSBIE. I think in preparing our defenses, that we somehow or other must put the information which we now have into engineers' and architects' offices so that they can provide routinely the sort of protection which we know is needed. Dr. Libby mentioned in his remarks that this might cost very little.

Now for too long we have known that some materials are functionally equal to other materials and competitive in price, but from the point of view of providing protection against nuclear reactions are far superior. Also, we know it takes quite a while to make changes when one is affecting parts of our economy and ways of doing things.

For instance, we have known for a long time that hard smooth materials are much better in the face of fallout contamination than rough materials.

We have known for a long time that certain frailable, frangible building materials under blast conditions break into thousands of fragments, each one a potential casualty producer.

So we need to reorient our thinking somewhat to recognize that we are living in an atomic age, and if we never had to face a war—for instance, we should not expect to have lower radiation levels. So we need to recognize the materials that are useful to us, and we need also to recognize that changes in design of a thing as simple as a house can provide additional protection merely by leaving out basement windows.

We have forgotten that basement windows were put in houses years ago when our forefathers lighted the basement by daylight, but no one ever turns off a light today because the room has a window. So we could build a basement cheaper and probably ventilate it as efficiently without openings as with openings.

Also, if as simple a concept as the fact that protection against radiation is closely related, almost proportional, to unit-area density of material between the contaminated area and the safe area could be put in the drafting rooms, then the people who are experts in design and selection of materials, might start substituting say concrete floors in typical residences for wood floors. By such means you might have as good a basement shelter in a one-story wood rambler house as you now have in a two-story house.

Chairman HOLIFIELD. Mr. Durham?

Representative DURHAM. Referring to your statement in regard to this projected future, and of course you have made this study—you can prepare yourself to take so much destruction of human lives and human property.

We have to assess it on that basis and then come up with some kind of an answer as to whether or not we could take a loss of 40 million people and whether we could take a loss of 50 percent of all property, food, and everything else.

I would like to have the panel comment on that.

I think it would be very interesting in dealing with the approach as to what we may think of in the future. I believe you did approach it in the future, not presently.

Mr. KAHN. Yes.

Representative DURHAM. That is we are reaching the place here where we can't get enough money or we can't find enough funds unless we all do it individually in trying to portect ourselves, and there seems to be very little interest, with all the effort we have put out here and put out in the agency.

If the panel would care to comment on that I thought it was a very intriguing and interesting point in the future picture of wars that we may face in the next 30, 40, or 50 years.

Mr. KAHN. Or even less than that.

Representative DURHAM. Less than that.

Mr. KAHN. Right. The question of what you are willing to accept in the way of a retaliatory blow depends a great deal on the provocation.

In other words, the Russians have done things to us and maybe we have done things to them which 30 years ago would have meant war but today does not. The balance of terror is delicate but not that delicate. It is hard to overturn. However, if the Russians dropped a bomb on London just like that out of the blue, I think they would find bombs on Moscow, even if their retaliatory blow killed more than half of our country, simply because we would not even stop to think.

We would just react.

On the other hand, if we had made no preparation to accept a retaliatory blow and the Russians got us to a Munich-type conference say 5 or 10 years from now after they had us put into a very tense period and made us think about it and then relaxed us and then raised us again to a peak of tension and then relaxed us—just the way Hitler did, he gave us a model.

Representative DURHAM. I understand you think, of course, under that circumstance that they are going to try to come up with an answer as to how much they are willing to take before they ever drop that bomb?

Mr. KAHN. That is right. They can test you experimentally and find out gradually what you are willing to take, and they can probably do it reasonably safely.

They can't do it completely safely. They run some risks.

But there is another point to realize: It does not have to be down in black and white before our NATO relations get influenced. They can think just as well as we can, in some cases they can think better because they are closer to the gun.

In the past the Europeans have resolutely refused to look at this problems because it was too horrible. But it is getting closer and at some point you have to look even horror in the face. You are forced to. At that point when they start asking the question, "Will we give up New York for Paris, will we give up New York and Washington for London", you have to give them a story which sounds reasonable, at least to them if not to yourself.

You have to because they are going to ask for it. Now you may give them a story which sounds reasonable to a certain percent of the people but to others it won't. It then becomes a political issue, and the more you argue this thing the less credible it comes unless it has a modicum of rationality in it.

Representative DURHAM. With that kind of a plan what is the difference between that and a deterrence plan?

Mr. KAHN. What kind of a plan?

Representative DURHAM. A deterrence plan under which we are operating at the present time?

Mr. KAHN. Let me be very careful. It is in a sense the old massive retaliation that Secretary Dulles talked about in January 1954, but only in a quite different context. I do not believe that one should, even in the most indirect way, threaten massive retaliation for such incidents as Korea and Indochina.

These issues are just not big enough to justify world war III. In fact the less you talk about massive retaliation the better, up to the point where you get to really serious issues like all of Europe or even a piece of Europe, but where the principle involved is a really big issue. At that point you have two choices. You can try to defend it with limited war forces on the ground, or you can try to defend it by Strategic Air Command.

For the last 4 or 5 years the Strategic Air Command has been a very credible defense of Europe. I personally think this defense will still be credible for some period in the future, though some critics have cast doubt on its credibility. In any case, our resolve to use SAC is rapidly diminishing in credibility. Furthermore, you have to take account of a peculiar human reaction which tends to anticipate trends and acts as if the future is already here.

In other words, the Russians test a missile so some Europeans and Americans act as if they have 500 missiles in existence. This is a human reaction, to look at a trend and anticipate it arrival prematurely.

Representative DURHAM. We are getting over the base, Mr. Chairman.

Mr. KAHN. My apologies, the only point I'm trying to make is that Type II Deterrence is a form of massive retaliation if you will, but on an issue which may be worth it. It has been credible in the past. It

is credible now. It may not be credible in the future for just such reasons as given in the testimony we have had in the last 4 days.

Dr. LIBBY. I think, Mr. Chairman, that by pursuing the program of hope and of citizen's individual action program, we may develop a knowledge of the realities which will make people better able to assess the factors Dr. Kahn has brought out. So I think we ought to encourage the kind of development that we have been talking about in the way of getting citizens to take action in the program.

Some of these things cost very little money really, and examples were given during these hearings, but these are by no means the only things that individuals can do. There is the problem of food supply, for example. There is a problem of the recovery of farmlands. We need much more research on just how we can recover contaminated farmland and return it to usefulness.

I must say that what little work we have done so far has not led us to believe that it is a very easy job. But there may be things we have not discovered, which can be done to help greatly.

We have logistic problems in the case of an attack which need further analysis. We talk about country A and country B, but the country B is used to depending on the cities in its livelihood. And with the evacuees that Mr. Kahn mentioned from country A to country B, it has a doubly difficult problem of just continuing to survive. In thinking about these ordinary problems from the point of view of the individual as well as from the Government point of view, a dual attack on it will lead to some increase in the public knowledge of the threat and then our democratic processes will operate to give us a national position which the people can back and understand.

Chairman HOLIFIELD. The question has been asked the Chair why have we had testimony on post-protective measures? The Chair would like to state that, of course, this committee does not have civil defense under its jurisdiction. We felt that in presenting a picture of an attack like this to the American people, it was our obligation not to paint a picture which we believed is realistic even though it be black, and yet not say that there is some hope.

We did not, of course, bring these protective measures into the hearing as an indication that we favored building a maginot line in America or any of those sort of things.

It is very difficult to hold a hearing in which someone doesn't criticize the method of the hearings or the motives of the hearings.

We felt that it was to balance the testimony, as nearly as the facts seem to be to people who have given a great deal of study to it, that this point should be brought into the hearings before we close.

And that is the answer to that.

I have also been asked the question why the detailed effects of this pattern of attack were applied to our own country and not to some country overseas. The obvious answer to that is we are primarily concerned with the safety naturally of our own inhabitants. There is also the corollary factor that we do not want to be accused of proposing a war plan against another country; this committee doesn't. Then, following that, the question has been posed, Why did the pattern contain 2,500 megatons on our overseas bases and on a post-attacking nation? This was done on the same basis of reasoning as the original pattern, strictly for the purpose of obtaining the readings

REPRESENTATIVE HOSMER:

hearings if they have done nothing else have emphasized the necessity of very wisely proceeding with the business of minimizing those risks.

Now that doesn't mean giving up because that bears a price tag that is greater in my mind than the risk of nuclear war.

It does mean, however, going about in relaxing world tensions in a manner which will accomplish it, not in the pursuit of an illusion of peace but in a pure suit of a practical means of achieving it. And that often requires courage and wisdom and chance taking in and of itself.

I think this Nation is capable of doing that. We are not the first generation of Americans who have faced difficult choices.

The choice between slavery and possible death. I think we are as I say capable of handling the situation, running the risk and avoiding the sad choices.

Chairman HOLIFIELD. Dr. Kahn, let's plan to close the hearing in a few short minutes.

Dr. TOMPKINS. I would like to put into the discussion if I may just a few personal views of my own as to what the nature of this problem is.

I had the experience of being on the Manhattan District in 1943. I am very familiar with the psychology of revulsion against the effect these weapons can produce. As a matter of fact, I was part of a group which shortly after 1945–46 attempted in our own minds to conceive of an attack just about the kind that you have laid down. It is entirely true that in the absence of experience, in the absence of information and in the absence of data, the impression that all of us have as to the consequences of such an attack were virtually of the complete and total saturation variety, namely there would literally be nothing left after such an event.

Now this was 10 years ago. After that period it became quite apparent, at least to my mind, that an event such as we have examined here is not one that anyone would take willingly, but which we would be very smart to ask ourselves if it were imposed on us would we be able to come through it?

Now this is a different question. This is my view of the role of civil defense.

I don't think any of us will accept this kind of result willingly unless the stakes were well beyond our individual choices. That isn't the role that nonmilitary defense plays in at least my life.

With the passage of time, that is since the 1945–46 period, we have examined the results of a very major attack. We have found in these hearings what from 10 years' experience I know to be true, namely, the results are catastrophic enough in their own right. They need no imaginary amplification. The facts themselves are bad enough. However, it is crucially important to look those facts squarely in the face if one is going to face the necessity for survival, if against your will or despite anything you can do about it, it is imposed on you. As far as I am concerned, if the chips ever go down and avoiding a conflict is not possible in the scheme of human events of the future, I for one do not propose to see this Nation come out the loser.

And therefore, I think we should be able to take it if we have to.

Now following up Herman's point of view, I think the technology is such that complete protection is absolutely out of the question.

Therefore the concept that any protective measures that we take puts us in the position of adopting a maginot line concept behind

which we hide, or developing ourselves into fortress America is entirely false. That is not the role of the nonmilitary defense in the world of the future.

The world of the future is going to be dangerous. The human capacity to inflict such damage will inevitably be there. The threat of the employment of that damage is something with which we will have to live unless something very drastic changes in our international relations. We must know how to react to it. I personally never exject to see consequences of the type displayed on these maps. If we really thought this, if we really thought that there was no hope of getting around it, then I think one would be entitled to be discouraged.

As far as I am personally concerned, by looking at the problems, understanding what they are composed of, and by necessity being an incurable optimist, I never expect to see a war of this kind happen. It is possible that more limited engagements of a more sharply defined type will be fought under the sword of Damocles hanging over our heads some time in the future. If so, let us be prepared for that. So, that at least, is my personal view as to the role that the nonmilitary defense should play, and it will never be perfect.

Chairman HOLIFIELD. Many of the witnesses who have appeared before this committee this week and the members of this committee have for many months and years been carrying a heavy burden of responsibility of knowledge of these things on their minds and in their hearts.

Some of us have felt that it is time to share this burden of responsibility with the American people. Before we adjourn I want to thank the reporters who have attended these hearings so patiently and the people on the TV and radio, the representatives in those media. I want to thank the members and especially I want to thank Mr. Hosmer, because I believe he sat in his chair as many hours as I have sat in mine.

I want to thank the staff, which has worked on this hearing some 6 weeks. Particularly do I want to thank Colonel Lunger who has worked many nights to 2 and 4 o'clock in order to make these hearings possible the next day and also Dr. Carey Brewer whom we borrowed from another subcommittee, the Subcommittee on Military Operations, for these past few weeks.

I want to thank the audience too that has attended these hearings and compliment them on the way they have listened, attentively and quietly, to the sometimes long, complicated, and technical testimony that has been given in some instances.

These long technical testimonies were necessary in order that the basic record might be presented in as fair a way as we know how.

In conclusion I want to say the challenge of the nuclear age is enormous and inescapable.

The facts of nuclear war and the effects of nuclear war once established will not fade away because they are unpleasant. If we are prudent we will not ignore them.

They will not disappear. Each of us must accept personal responsibilities because the nuclear war is a personal threat to our survival.

The problem is too large to leave solely in the hands of the diplomats and the generals. They need the collective thinking and advice of every thinking human being in the world.